



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>6</sup> :</b> <b>H04Q 1/14, H01R 17/12, H04N 7/10</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 98/25416</b> <b>(43) International Publication Date:</b> 11 June 1998 (11.06.98)
<b>(21) International Application Number:</b> PCT/US97/22556 <b>(22) International Filing Date:</b> 8 December 1997 (08.12.97)  <b>(30) Priority Data:</b> 08/761,525      6 December 1996 (06.12.96)      US  <b>(71) Applicant:</b> ADC TELECOMMUNICATIONS, INC. [US/US]; 12501 Whitewater Drive, Minnetonka, MN 55343 (US).  <b>(72) Inventors:</b> ANDERSON, Andrew, R.; 600 North Lilac Drive #205, Golden Valley, MN 55422 (US). BACKES, Glen, B.; 8662 North Old Highway Road, St. Cloud, MN 56301 (US). DEMULLING, Richard, T.; 3460 - 92nd Court, Circle Pines, MN 55014 (US). LOUWAGIE, Dominic; 15980 North Hillcrest Court, Eden Prairie, MN 55346 (US). ORTBERG, Todd, C.; 2221 Lukewood Drive, Chanhassen, MN 55317 (US). SANSONE, Edward, F.; 2672 - 106th Lane N.W., Coon Rapids, MN 55433 (US).  <b>(74) Agent:</b> BRUESS, Steven, C.; Merchant, Gould, Smith, Edell, Welter & Schmidt, P.A., 3100 Norwest Center, 90 South Seventh Street, Minneapolis, MN 55402-4131 (US).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the</i> <i>claims and to be republished in the event of the receipt of</i> <i>amendments.</i>
<b>(54) Title:</b> RF CIRCUIT MODULE  <b>(57) Abstract</b>  A module for radio frequency signal circuits includes an electrically conductive housing. Coax connectors are secured to the rear face of the housing. A circuit board is contained within the interior spaced between sidewalls of the housing. A ground side of the circuit board includes a layer of electrically conductive material which is electrically connected to the housing. Coax cables extend within the interior of the housing from the coax connectors and between the ground side of the circuit board and an opposing sidewall. An opposite side of the circuit board contains circuit components inter-connected with one another through a plurality of circuit paths.		

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## RF CIRCUIT MODULE

### I. BACKGROUND OF THE INVENTION

#### 1. FIELD OF THE INVENTION

5 This invention pertains to circuits for broad-band RF systems. More particularly, this invention pertains to modular RF (radio frequency) circuit components.

#### 2. DESCRIPTION OF THE PRIOR ART

10 In the telecommunications industry and more particularly in the video transmission industry, broad-band radio frequency (RF) signals (i.e., 5 MHz to 1 GHz) are carried over coax conductors from a headend to consumers. At the headend of the system, numerous signals are manipulated to achieve a wide variety of functions and objectives. For example, signals carried on numerous coax cables may be combined onto a single coax conductor. Similarly, a signal on a main coax  
15 conductor may be divided into a plurality of signals carried on branch coax conductors. Additionally, signals may be added or removed from a main conductor through directional couplers or the like.

In addition to combining, splitting, diverting or adding signals, the headend will also include apparatus for modifying signals. For example, in order to  
20 adequately tune the system, it may be desirable to provide attenuators or the like to attenuate a signal to a desired level. Further, as a broadband RF signal is carried over a length of cable, the high frequency range of the signal may be attenuated more than a low frequency range of the signal. As a result, equalizers are utilized to modify the signal to have a level intensity throughout its frequency range.

25 Throughout the system, performance characteristics are critical. For example, a common performance criteria is to maintain the flatness of a signal. Flatness refers to maintaining a level intensity of a signal throughout its frequency range. For example, if the signal is attenuated by 2 dB at 1 GHz, then it is desirable that the signal be attenuated at 2 dB at the 5 Mhz frequency. Further, the system  
30 needs to be tuned for impedance matching.

Prior art headends include a wide variety of devices to accommodate and accomplish the functions described above. It is desirable to provide an apparatus to accommodate the various functions required at the headend through a modular construction to permit ease of maintenance and cable management in a  
35 headend. Such a device must accommodate the performance characteristics of the

headend while permitting the modular construction to enhance the cable management and organization of a headend.

## **II. SUMMARY OF THE INVENTION**

According to a preferred embodiment of the present invention, a  
5 module is provided for containing a circuit for performing discrete functions on a radio frequency signal. The module comprises a housing of electrically conductive material. The housing has a front face and an opposite rear face. The front face and rear face are separated by opposite sidewalls and opposite end walls. A plurality of coax connectors are secured to the rear face with an outer shield of the connectors  
10 electrically connected to the housing. A circuit board is contained within the interior. The circuit board is generally parallel to and spaced between the sidewalls. The circuit board has a component side and a ground side. The ground side includes a layer of electrically conductive material which is electrically connected to the housing. A plurality of connection locations are provided on the ground side of the  
15 circuit board. Each of the connection locations includes a ground connection for connecting to the layer of electrically conductive material. The component side of the circuit board includes a plurality of circuit components interconnected with one another and with the connection locations through a plurality of circuit paths. The coax connectors are connected to the connection locations. The outer shields of the  
20 connectors are connected to the ground connections of the connection locations. In one embodiment, a plurality of coax cables connect the individual coax connectors with the connection locations, with the ground shields of the coax cables connected to the outer shields of the connectors and the ground connections of the connection locations, and with the cables disposed between the ground side of the circuit board  
25 and the opposing sidewall of the housing.

## **III. BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 is a bottom end, front face and right sidewall perspective view of one embodiment of a module according to the present invention shown in exploded view (with internal cables omitted);

30 Fig. 2 is a left side plan view of the module of Fig. 1;  
Fig. 3 is a right side plan view of the module of Fig. 1;  
Fig. 4 is a front elevation view of the module of Fig. 1;  
Fig. 5 is a rear elevation view of the module of Fig. 1;  
Fig. 6 is a bottom end view of the module of Fig. 1;  
35 Fig. 7 is a top end view of the module of Fig. 1;

Fig. 8 is a rear, right side and top end exploded view of the module of Fig. 1 with a cover removed;

Fig. 9 is a perspective view of internal components of the module of Fig. 1;

5 Fig. 9A is a top plan view of a printed circuit board and attached components;

Fig. 10 is an opposite side plan view of the components of Fig. 9;

Fig. 11 is a side cross-sectional view of the module of Fig. 1;

10 Fig. 12 is a view similar to that of Fig. 1 showing in exploded format an alternative embodiment of the present invention;

Fig. 13 is a right side plan view of the module of Fig. 12;

Fig. 14 is a left side plan view of the module of Fig. 12;

Fig. 15 is a front elevation view of the module of Fig. 12;

Fig. 16 is a rear elevation view of the module of Fig. 12;

15 Fig. 17 is a bottom end view of the module of Fig. 12;

Fig. 18 is a top end view of the module of Fig. 12;

Fig. 19 is a bottom end, front face and right sidewall perspective view of a third embodiment of a module according to the present invention shown in exploded view (with internal cables omitted);

20 Fig. 20 is a right side plan view of the module of Fig. 19;

Fig. 21 is a left side plan view of the module of Fig. 19;

Fig. 22 is a front elevation view of the module of Fig. 19;

Fig. 23 is a rear elevation view of the module of Fig. 19;

Fig. 24 is a bottom end view of the module of Fig. 19;

25 Fig. 25 is a top end view of the module of Fig. 19;

Fig. 26 is a perspective view of a first embodiment of a chassis for holding modules according to the present invention;

Fig. 27 is a perspective view of a second embodiment of a chassis for holding modules of the present invention; and

30 Fig. 28 is a perspective view of a third embodiment of a chassis for holding modules of the present invention.

#### **IV. DESCRIPTION OF THE PREFERRED EMBODIMENT**

Referring now to the several drawing figures in which identical elements are numbered identically throughout, a description of the preferred  
35 embodiment of the present invention will now be provided.

With initial reference to Figs. 1 through 11, a module 10 according to the present invention will be described for use as a splitter/combiner module for

splitting a main signal into a plurality of branch signals or, alternatively, combining a plurality of branch signals into a common main signal. The module 10 includes a housing having a front face 14, a rear face 16. The front face and rear face 14, 16 are separated by opposing sidewalls 18, 20 and opposite end walls 22, 24. The housing 12 is formed of electrically conductive material. Preferably, the material is nickel-plated aluminum.

Sidewall 18 and end walls 22, 24 are integrally formed as a box configuration with walls 22, 24 having inwardly protruding peripheral ledge 26. Rear wall 16 is secured to walls 18, 22, 24 by screws 28. The sidewall 20 is fastened to the ledge 26 by a plurality of screws 28 received in aligned bolt holes of sidewall 20 and threaded bolt holes 32 on the peripheral ledge.

The sidewall 20 is sized to have a length greater than the longitudinal dimension between walls 22, 24 such that ends 20a, 20b extend beyond ends 22, 24 as flanges for purposes that will be described.

The front cover 14 includes extending edges 14a, 14b which extend beyond ends 22, 24. The front cover further has an internal ledge 34 (shown in Figs. 1, 8 and 11) on an interior surface of the cover 14. The ledge 34 is sized to extend into the interior of the housing when the front cover 14 is attached to the housing.

The front cover 14 and sidewall 20 are secured to the housing by the screws 28 received within aligned bolt holes. The screws 28 are preferably positioned at one-half inch on-center spacings to prevent EMI leakage as is conventional.

The front cover 14 includes a plurality of openings 36 the function of which will be described with the openings 36 arranged linearly along the face 14. Similarly, the front cover 14 includes an opening 38 sized to pass a coax connector 41 for purposes that will become apparent.

A plurality of coax connectors 40-0 through 40-8 are secured to the rear face 16. Each of the coax connectors is identical. Such connectors are conventional and include a central conductor surrounded by a grounded shield. The grounded shields of the coax conductors are in direct physical and electrical contact with the electrically conductive material of the rear face 16.

Contained within the interior of the housing 12 is a printed circuit board 44. The printed circuit board 44 is supported on posts 42 by screws 43. The posts 42 are electrically conductive and connected to wall 18. The printed circuit board 44 includes a component side 44a and a ground side 44b (see Fig. 9). The ground side 44b opposes the wall 18 and the component side 44a opposes wall 20.

The printed circuit board 44 is maintained in parallel, spaced relation between the walls 18, 20 by supports 42.

A layer 44c (Fig. 9) of electrically conductive material (such as a sheet layer of copper) is provided on the exterior surface of surface 44b.

5 A plurality of coax cable connection locations 48-0 through 48-8 are provided on the ground side 44b of the printed circuit board 44. Each of the coax cable connection locations 48-0 through 48-8 include a ground connection for connecting the ground shields of a coax cable to the conductive layer 44c.

10 A plurality of circuit components are disposed on the component side 44a of the printed circuit board 44. In the embodiment shown, the components include a solid state directional coupler 50 and three solid state splitter/combiners 52-1, 52-2 and 52-3.

It will be appreciated that a solid state directional coupler 50 is a commercially available item, and an example of such is a 20dB coupler Product  
15 No. CPL/20BE-08A3 sold by TRAK Microwave, 4726 Eisenhower Blvd., Tampa, FL 33634-6391. Similarly, solid state splitter/combiners 52-2 through 52-3 are commercially available one-by-four splitters and examples of such are Product No. SPL/4BE-53D sold by TRAK Microwave. Splitter/combiner 52-1 is a one-by-two splitter such as Product No. SPL/2BE-53D of TRAK Microwave.

20 The splitter/combiners each receive a signal and divide an RF signal into two signals of equal strength. Splitter/combiners 52-2 and 52-1 are electrically connected in series. Similarly, splitter 52-3 is connected in series with splitter 52-1 such that splitter 52-3 is connected in parallel to splitter 52-2.

The electrical connection of the components 50 and 52-1 through  
25 52-3 is provided through a plurality of circuit paths 53 (Fig. 9A) contained on the surface 44a where the circuit paths connect the components 50, 52-1 and 52-3 with the coax connection locations 48-0 through 48-8. The circuit paths connect the components and the connection locations such that connector 40-0 is connected to the directional coupler 50 with a portion of the signal diverted from the directional  
30 coupler 50 to the coax monitor connector 41 through cable 41-1. Preferably, coupler 50 provides a -20dB monitor signal.

The main signal from the directional coupler 50 is passed to the splitter/combiner 52-1 which divides the main signal into two signals with one  
35 passed along the circuit paths to splitter/combiner 52-2 and the other passed to splitter/combiner 52-3. Each of splitters 52-2 and 52-3 split a signal into four signals resulting in a total of eight branch signals passed to connection locations 48-1 through 48-8.

In the preceding paragraph, a signal is described as coming into the directional coupler from connector 40-0 and then eventually split and passed to connectors 40-1 through 40-8. With the directional coupler 50 arranged in the schematic shown of Fig. 3, such a signal flow path would result in losing a monitor function at monitor port 41. With this schematic shown in Fig. 3, signals passed into connectors 40-1 through 40-8 are attenuated and combined to a main signal which is then passed through directional coupler 50 to OUT port 40-0. A portion of the main signal is then passed from the directional coupler 50 to the monitor port 41 so that the signal may be monitored. If it is desirable to pass a signal into connector 40-1 for division into branch signals distributed to connectors 40-1 through 40-8, a different directional coupler 50 can be provided such that a signal from connector 40-0 can be monitored at port 41.

Before the branch signals are passed to the connection locations, they are passed through attenuator components. Each of the attenuator components is identical and includes a base member 60-1 through 60-8 which is secured to the component side 44a of the printed circuit board 44 along a leading edge 44d of the printed circuit board and with the base members 60-1 through 60-8 arranged in a linear array.

A plurality of the attenuator plugs 64-1 through 64-8 are provided to be releasably connected to individual ones of the base member 60-1 through 60-8. The attenuator plugs 64-1 through 64-8 provide an attenuation to each of the branch signals being sent to connectors 40-1 through connectors 40-8.

Attenuator plugs and base members are commercially available items such as those sold as Product No. F-7520-A (for a 20dB attenuator) through Communication Associates 1750 T-Coleman Road, Anniston, AL 36207. The plugs 64-1 - 64-8 can be individually selected to provide a discrete amount of attenuation to a signal. For example, a "zero" plug can be inserted into a base member to provide 0 dB attenuation. Alternatively, at an option of a technician, the 0 dB plug may be replaced with a 15 dB plug to provide 15 dB attenuation to a signal. As a result, each of the branch circuits can be individually provided with a unique attenuation selected at an option of a technician. The holes 36 on the front face 14 are arranged and sized such that each of the attenuator plugs extends through individual ones of the holes 36 to be grasped by an operator. As a result, an operator can remove and replace an attenuator plug without needing access to the interior of the housing 12.

To provide EMI leakage protection, the front face 14 is provided with a removable cover 100 surrounding the array of holes 36. A deformable, conductive seal 102 (silicon gasket impregnated with silver particles) is provided between the



cover 100 and face 14. Threaded connections 104 on the cover 100 are aligned with threaded holes on the standoff posts 106 such that the cover 100 can be secured to the face 14 by turning the threaded connectors 104 into the standoff posts 106. As the threaded connection 104 is tightened, the edge of the cover 100 compresses into the seal 102 to thereby compress the seal 102 against the face 14 to provide an effective EMI seal.

The device thus described performs splitter/combiner functions with connector 40-0 being a main connector and with connectors 40-1 through 40-8 being branch connectors. In other words, a signal admitted to connector 40-0 is split into eight equal signals passed to connectors 40-1 through 40-8. Further, the main signal may be monitored through forward connector 41.

As shown in the drawings, all of the connectors 40-0 - 40-8 are connected to the connection locations 48-0 - 48-8 via coaxial cables 70-0 through 70-8 such that the ground shield of the coaxial cable is electrically connected to the ground shield of the connectors 40-0 through 40-8, respectively, as well as connected to the conductive layer 44c.

In RF circuits, impedance matching is critical. The parallel relation of the electrically conductive layer 44c to the sidewall 18 of the housing 12 presents a small capacitance. Further, the spaced relation of the circuit paths 53 to the opposite sidewall 20 presents a minute capacitance. Capacitance between the housing and the circuit components are referred to as "parasitic reactance". Further, there is natural capacitance or reactance of components on the circuit board 44. The pathways 53 are tuned to balance the capacitance. The pathways 53 are tuned by adjusting the size of the circuit pathways 53 such that they present an inductance selected to balance the parasitic reactances and the circuit board reactances. It will be appreciated that sizing circuit pathways to present a desired impedance is well known in the art. Also, the cables 70-0 through 70-8 are routed between the ground surface 44c of the circuit board 44 and its opposing sidewall 18 of the housing 12. By routing the cables 70-8, 70-8 on this side of the circuit board 44 and avoiding placing the cables adjacent any of the circuit components or circuit pathways, undesirable reactances are avoided.

With the structure thus described, the desired circuit function is attained in a modular format. Further, in addition to impedance matching circuit components, the selection and arrangement of components permits a high performance module with impedance matching throughout and with desired flatness of a signal across the broad band frequency range.

As shown in the drawings, the forward ledge 34 includes a plurality of resilient spring contacts 35 mounted on the ledge 34 and positioned to swipe

against the electrically conductive layer 44c as the cover 14 is placed on to the housing to insure enhanced electrical contact between the conductive layer 44c and the cover 14 so that all elements are grounded when coaxial cables are connected to the rear connectors.

5 To further protect the signal, the front cover 100 is provided on front end 14 to cover and enclosed all attenuator plugs 64-1 - 64-8 extending through holes 36. The cover 100 prevents EMI interference which would otherwise occur by uncovered plugs 64 extending through holes 36.

10 The foregoing discussion with respect to Figs. 1-11 described an embodiment of the present invention for an RF module having splitter functions and monitor functions. Figs. 12-18 illustrate the invention in a different embodiment for an equalizer circuit. In an equalizer circuit, an equalizer component is used to provide the same degree of attenuation at the extremes of the RF bandwidth. Elements similarly numbered with respect to the previously described embodiment  
15 are numbered similar in Figs. 12-18 with the addition of an apostrophe to distinguish between the embodiments.

In Fig. 12, a module 10' includes a housing having a base 18' and end walls 22', 24'. The module 10' further includes a front face 14' and a rear face 16'. A side cover 20' closes the module 10'.

20 As in the previously described embodiment, the present invention incorporates a printed circuit board 44' containing circuit components. The circuit board 44' is maintained in parallel spaced relation between the sidewall 20' and the lower sidewall 18' by support posts 42' and associated screws 43'.

For the equalizer circuit, the circuit components include a directional  
25 coupler 50' and an equalizer component 64' removably secured to a base member 60'. The equalizer 64' may be removed or replaced through an opening 36' in the forward wall 14'.

The rear wall 16' contains coax connectors 40-0', 40-1' and 40-2'. Coaxial cables (not shown) extend from the coax connectors 40-0' through 40-2' and  
30 beneath the printed circuit board 44' in a manner identical with that previously described. Further, as in the previous embodiment, the circuit board 44' contains an electrically conductive layer opposing and electrically connected to surface 18'. Also, the circuit paths on the upper surface of the board 44' are provided to balance impedances as previously described.

35 The coaxial cables will extend between the board 44' and the surface 18' for reasons previously discussed. The circuit paths on the board 44' are disposed such that an incoming signal from 40-0' is passed to the equalizer and then to the directional coupler 50'. Further, the separate incoming signal can be passed from

connector 40-1' to directional coupler 50' encoupled with the signal from the equalizer 64' with the coupled signal passed to the output connector 40-2'. A support 51' is mounted within the interior of the housing to guide equalizer 64' toward base member 60' in required alignment. As with the previous embodiment, a cover 100' covers the front face 14' together with a gasket 102' to prevent EMI.

All other features of the module 10' are similar to the module 10 including the external dimensions and tabs of the module such that a module 10' may be interchangeable in a chassis with a module 10. Further, the module 10' has the same impedance matching and parasitic reactance compensation previously mentioned with respect to module 10. As a result, the invention of module 10 is incorporated into module 10' with module 10' showing a specific embodiment of the invention for use with an equalizer component. It will be appreciated that equalizer components 64' are commercially available items. An example of such is product number G75-000 of ADC Broadband Communications Division, 999 Research Parkway, Meridan, CT 06450.

Figs. 19-25 illustrate a third embodiment of the present invention for use in a 6-port directional coupler. The directional couplers are used to split or add multiple signals. Elements similarly numbered with respect to the previously described embodiments are numbered similarly in Figs. 19-25 with the addition of a double apostrophe to distinguish between the embodiments.

In Figs. 19-25, a module 10" includes a housing 12" having a base 18" and end walls 22", 24". The module 10" further includes a front face 14" and a rear face 16". A side cover 20" closes the module 10".

As in the previously described embodiments, the present invention incorporates a printed circuit board 44" containing circuit components. The printed circuit board 44" is maintained in parallel spaced relation between the sidewall 20" and the lower sidewall 18" by support post 42" and associated screws 43".

The circuit components include six directional couplers 50-1" through 50-6", each with individually associated attenuator plugs 64-1" through 64-6" which are removably secured to individual base members 60-1" through 60-6". Each of the attenuator plugs 64-1" through 64-6" may be removed or replaced through openings 36" in the forward wall 14".

The rear wall 16" contains coax connectors 40-0" through 40-6". Coaxial cables (not shown in Figs.) extend from each of the coax connectors 40-0" through 40-6" and beneath the printed circuit board 44" in a manner identical with that described with reference to the first preferred embodiment of Fig. 1. Further, as in the previous embodiment, circuit board 44" contains an electrically conductive layer opposing and electrically connected to surface 18". Also, the circuit paths on

the upper surface of the board 44" are provided to balance impedances as previously described.

The coaxial cables will extend between the board 44" and the surface 18" for reasons previously discussed. The circuit paths on the board 44" are disposed such that six incoming signals may be separately connected to each of connectors 40-1" through 40-6" and passed through the individual attenuators 64-1" through 64-6" into the directional couplers 50-1" through 50-6" where the six signals will be joined into a common output signal passed to connector 40-0". As with the previous embodiment, a cover 100" covers the front face 14" together with a gasket 102" to prevent EMI.

All of the features of the module 10" are similar to the modules 10, 10' including the external dimensions and tabs of the modules such that the modules 10", 10' and 10 may be interchangeable in a common chassis. Further, the module 10" has the same impedance matching and parasitic reactance compensation previously mentioned with respect to module 10. As a result, the invention of modules 10 and 10' is incorporated into module 10" with module 10" showing a specific embodiment of the invention for use with a 6-port directional coupler circuit.

Fig. 26 shows a first chassis 200 for housing a plurality of modules 10. The chassis 200 includes horizontally spaced apart sidewalls 202,204 and vertically spaced apart top and bottom walls 206,208. The top and bottom walls 206,208 are spaced apart by a distance substantially equal to a distance between the end walls 22,24 of the module 10.

Each of the top and bottom walls 206,208 includes a plurality of vertically aligned grooves 210. The grooves 210 are sized to slidably receive the projecting flanges 20a,20b of the module 10 such that a module may be slidably inserted into the frame 200 with the modules 10 vertically positioned. In the embodiment shown, there are 12 pairs of vertically aligned grooves 210 such that 12 modules may be inserted into the frame 200. Since the flanges 20a,20b of the modules 10 are offset from a longitudinal plane of the module 10, the grooves 210 are offset from module receiving spaces so that the entire open space between the sidewalls of the frame may be filled with modules. Also, the grooves 210 are spaced apart a distance selected such that as modules are slidably inserted into the frame, adjacent modules are positioned with a small spacing between opposing sidewalls of adjacent modules 10.

Locking screws 214 are provided on the projecting tabs 14a,14b of the front walls 14 of the modules 10. Corresponding threaded locking holes 216 are provided on both the top and bottom walls 206,208 of the frame 200. The screws

214 are not centrally positioned on the tabs 14a,14b. Instead, they are laterally offset from a central longitudinal axis of the front wall 14. The holes 216 are similarly offset to require that a module 10 be placed in the frame 200 in a desired orientation and cannot be flipped 180° to be inserted in an undesired orientation. The frame 200  
5 also includes a hinged cover 218 which preferably is transparent to permit an operator to inspect the interior. Cable management brackets 220 are provided on the rear of the chassis 200.

From time to time, a customer or purchaser of the modules 10 may desire to hold the modules 10 in a horizontal alignment rather than the vertical  
10 alignment of Fig. 26. An alternative chassis 200' is shown in Fig. 27 for holding the modules 10 in a horizontal alignment. In Fig. 27, the chassis 200' includes horizontally spaced apart sidewalls 202',204' and vertically spaced apart top and bottom walls 206',208'. An intermediate wall 209' is provided midway and parallel to side walls 202',204'. The distance between either of side walls 202',204' and  
15 midwall 209' is equal to a distance between the end walls 22,24 of the module 10.

Each of the sidewalls 202',204' and the midwall 209' include a plurality of horizontally aligned grooves 210'. The grooves 210' are sized to slidably receive the projecting flanges 20a,20b of the module 10 such that a module may be slidably inserted into the frame 200' with the module 10 horizontally  
20 positioned.

In the embodiment shown in Fig. 27, there are six pairs of horizontally aligned grooves 210' on both sides of the center wall 209' such that the frame 200' can contain a total of 12 modules. As a result, chassis 200 and 200' give an operator the opportunity to contain the exact same number of modules 10 in  
25 either a horizontal or a vertical alignment as the operator may select.

Also, the locking screws 214 of the modules are aligned with locking holes 216' on the side walls 202',204' and mid wall 209'. Since the screws 214 are not centrally positioned on tabs 14a,14b, and the holes 216' are not centrally positioned in modules receiving spaces, a module 10 must be placed in the frame  
30 200 in a desired orientation and cannot be flipped 180° to an undesired orientation. As in the embodiment of Fig. 26, the frame 200' of Fig. 27 includes a hinged cover 218' and cable management brackets 220'.

Finally, Fig. 28 shows a chassis 200'' which may be used in the event that an operator does not wish to have a combined total of 12 modules but instead  
35 only wishes to have a fewer number of modules. Chassis 200' retains two modules 10 in side-by-side horizontal alignment and includes mounting brackets 201 for mounting to a frame structure so that an operator can elect to mount pairs of modules at a time rather than twelve modules 10. Frame 200'' is similar to frame

200' in that it has an intermediate wall 209'' between side walls 202'' and 204'' with the locking screws 214 received within holes (not shown) of walls 202'', 204'' and 209''.

**WHAT IS CLAIMED IS:**

1. A module for containing a circuit for performing discrete circuit functions on a radio frequency signal, said module comprising:
  - a housing of electrically conductive material defining an enclosed
  - 5 interior;
  - said housing having a front face and an opposite rear face separated by opposite sidewalls and opposite end walls;
  - a plurality of coax connectors secured to said rear face with an outer shield of said connectors electrically coupled to said housing;
  - 10 a circuit board contained within said interior and positioned generally parallel to and spaced between said sidewalls;
  - said circuit board having a component side opposing a first of said sidewalls and a ground side opposing a second of said sidewalls;
  - said ground side including a layer of electrically conductive material
  - 15 electrically connected to said housing;
  - a plurality of connection locations on said ground side of said circuit board, each of said connection locations including a ground connection for connecting to said layer of electrically conductive material;
  - said component side of said circuit board including a plurality of
  - 20 circuit components interconnected with one another and with said connection locations through a plurality of circuit paths;
  - said coax connectors connected to said connection locations, each of said outer shields of said coax connectors connected to said ground connections of said connection locations.
  - 25
2. A module according to claim 1, including a plurality of coax cables disposed within said interior and connecting said coax connectors to said connection locations, each of said coax cables having ground shields connected to said outer shields of said coax connectors and to said ground connections of said connection
- 30 locations, said plurality of cables routed for said cables to be disposed between said ground side of said circuit board and said second of said sidewalls.
3. A module according to claim 1 wherein said circuit paths are sized to have an impedance selected to balance a parasitic reactance between said circuit board and said housing.

4. A module according to claim 1 wherein said plurality of components includes splitter components for receiving a main signal from one of said connection locations and dividing said main signal into a plurality of branch signals delivered along said circuit paths to individual remaining ones of said connection locations.
- 5 5. A module according to claim 1 wherein said splitters components are adapted to act as combiner components for receiving said plurality of branch signals from said individual ones of said connection locations and combining said branch signals into said main signal delivered along one of said circuit paths to said one of said connection locations.
- 10 6. A module according to claim 4 wherein said splitter components includes at least a first splitter and a second splitter connected in series.
7. A module according to claim 6 wherein said splitter components includes a third splitter connected in series with said first splitter and in parallel with said second splitter.
- 15 8. A module according to claim 4 wherein said circuit components include a plurality of attenuators associated with individual ones of said branch circuits.
9. A module according to claim 8 wherein said attenuators include a variable attenuator component for varying an amount of attenuation of said attenuators.
- 20 10. A module according to claim 9 wherein said attenuators includes a first attenuator component mounted on said component side of said circuit board and said variable attenuator component removably secured to said first component with said variable attenuator component selected for a fixed desired attenuation.
11. A module according to claim 10 wherein:
- 25       said attenuators are positioned adjacent said front face;  
      said front face having an opening sized to pass said second variable attenuator component through said front face;  
      an electrically conductive cover releasably secured to said front face and sized to cover said opening.
12. A module according to claim 11 wherein said cover and said front face  
30 include an electrically conductive, mechanically deformable seal.



13. A module according to claim 1 wherein said front face is removable from a remainder of said housing and includes electrically conductive, mechanically resilient conductors extending between said front face and said layer of conductive material.

5 14. A module according to claim 13 wherein said front face includes a protruding ledge disposed to support a leading edge of said circuit card.

15. A module according to claim 4 wherein said circuit components include a directional coupler for diverting a portion of said main signal to a connector location connected to a monitor coax connector.

10 16. A module according to claim 15 wherein said monitor coax connector is exposed on said front face.

17. A module according to claim 1 wherein said circuit components include a directional coupler.

15 18. A module according to claim 17 wherein said circuit components include an equalizer for equalizing a radio frequency signal along a frequency range.

19. A module according to claim 18 wherein said equalizer includes a first equalizer component mounted on said component side of said circuit board and a variable equalizer component removably secured to said first component with said variable equalizer component selected for a fixed desired radio frequency equalization.

20

20. A module according to claim 19 wherein:

said equalizer is positioned adjacent said front face;

said front face having an opening sized to pass said second variable equalizer component through said front face;

25 an electrically conductive cover releasably secured to said front face and sized to cover said opening.

21. A chassis and module combination for permitting selective housing of a plurality of modules containing radio frequency circuits, said combination comprising:

30 A. a plurality of modules each having:

a housing of electrically conductive material defining an enclosed interior;

said housing having a front face and an opposite rear face separated by opposite sidewalls and opposite end walls, with each of said faces and sidewalls being of predetermined dimension and with said sidewalls being parallel to one another;

a plurality of coax connectors secured to said rear face with an outer shield of said connectors electrically coupled to said housing;

a circuit board contained within said interior and positioned generally parallel to and spaced between said sidewalls;

said circuit board having a component side opposing a first of said sidewalls and a ground side opposing a second of said sidewalls; said ground side including a layer of electrically conductive material electrically connected to said housing;

a plurality of connection locations on said circuit board, each of said connection locations including a ground connection for connecting to said layer of electrically conductive material;

said component side of said circuit board including a plurality of circuit components interconnected with one another and with said connection locations through a plurality of circuit paths;

said circuit components selected to perform a circuit function on a radio frequency signal supplied to one of said connectors and to provide an output radio frequency signal to a remainder of said connectors;

said coax connectors connected to said connection locations, each of said outer shields of said coax connectors connected to said ground connections of said connection locations;

each of said end walls having a projecting flange extending in a common plane generally parallel to said sidewalls and with said common plane offset from a central longitudinal axis of said housing; said front face including end portions extending beyond each of said end walls;

a locking member secured to each of said end portions and having a locking end extending through a rear surface of said end portions;

at least one of said locking members positioned offset from a longitudinal axis of said front face;

B. a first chassis having:

a first chassis frame including horizontally spaced apart first sidewalls and vertically spaced apart first top and bottom walls with said first top and bottom walls spaced apart by a distance substantially equal to a distance between said end walls of said modules;

each of said first top and bottom walls including a plurality of vertically aligned first grooves sized to slidably receive said projecting flanges;

said first grooves spaced along said first top and bottom walls for a predetermined number of said modules to be slidably received within said first frame in a vertical orientation with said longitudinal axis of said front face vertically disposed and with opposing sidewalls of adjacent modules narrowly spaced apart;

a plurality of first mating lock members on each of said first top and bottom walls and positioned to mate with said locking members of said modules when said modules are received within said first frame in a predetermined orientation and with said flanges received within said first grooves;

C. a second chassis having:

a second chassis frame including horizontally spaced apart second sidewalls and vertically spaced apart second top and bottom walls; an intermediate wall extending vertically between said second top and bottom walls and centrally positioned between said second sidewalls with said intermediate wall dividing said second frame into a left column and a right column;

said second sidewalls spaced from said intermediate wall by a distance substantially equal to a distance between said end walls of said modules;

each of said second sidewalls and intermediate wall including a plurality of horizontally aligned second grooves sized to slidably receive said projecting flanges;

said second grooves spaced along said second sidewalls and said intermediate wall for half of said predetermined number of said modules to be slidably received within said left column of said second frame in a horizontal orientation with said longitudinal axis of said front face horizontally disposed and with opposing sidewalls of adjacent modules narrowly spaced apart;

5 said second grooves further spaced along said second sidewalls and  
said intermediate wall for half of said predetermined number of said  
modules to be slidably received within said right column of said  
second frame in a horizontal orientation with said longitudinal axis of  
said front face horizontally disposed and with opposing sidewalls of  
adjacent modules narrowly spaced apart; and  
a plurality of second mating lock members on each of said second  
sidewalls and intermediate wall and positioned to mate with said  
locking members of said modules when said modules are received  
10 within said second frame in a predetermined orientation and with said  
flanges received within said second grooves.

22. A module for containing a circuit for performing discrete circuit functions on  
a radio frequency signal, said module comprising:

- 15 a housing of electrically conductive material defining an enclosed  
interior;  
said housing having a front face and an opposite rear face separated  
by opposite sidewalls and opposite end walls;  
a plurality of coax connectors secured to said rear face with an outer  
shield of said connectors electrically coupled to said housing;  
20 a circuit board contained within said interior and positioned generally  
parallel to and spaced between said sidewalls;  
said circuit board having a component side opposing a first of said  
sidewalls and a ground side opposing a second of said sidewalls;  
said ground side including a layer of electrically conductive material  
25 electrically connected to said housing;  
a plurality of connection locations on said circuit board, each of said  
connection locations including a ground connection for connecting to said layer of  
electrically conductive material;  
said component side of said circuit board including a plurality of  
30 circuit components interconnected with one another and with said connection  
locations through a plurality of circuit paths;  
said coax connectors connected to said connection locations, each of  
said outer shields of said coax connectors connected to said ground connections of  
said connection locations;  
35 said plurality of components including splitter components for  
receiving a main signal from one of said connection locations and dividing said main

signal into a plurality of branch signals delivered along said circuit paths to individual remaining ones of said connection locations;

said circuit components include a plurality of attenuators associated with individual ones of said branch circuits;

5                   said attenuators including a first attenuator component mounted on said component side of said circuit board and a variable attenuator component removably secured to said first component with said variable attenuator component selected for a fixed desired attenuation;

said attenuators positioned adjacent said front face;

10                   said front face having an opening sized to pass said second variable attenuator component through said front face; and

an electrically conductive cover releasably secured to said front face and sized to cover said opening.

15   23.    A module according to claim 22 , including a plurality of coax cables disposed within said interior and connecting said coax connectors to said connection locations, each of said coax cables having ground shields connected to said outer shields of said coax connectors and to said ground connections of said connection locations, said plurality of cables routed for said cables to be disposed between said  
20   ground side of said circuit board and said second of said sidewalls.

24.    A module according to claim 22 wherein said circuit paths are sized to have an impedance selected to balance a parasitic reactance between said circuit board and said housing.

25   25.    A module according to claim 22 wherein said splitters components are adapted to act as combiner components for receiving said plurality of branch signals from said individual ones of said connection locations and combining said branch signals into said main signal delivered along one of said circuit paths to said one of said connection locations.

26.    A module according to claim 22 wherein said splitter components includes at  
30   least a first splitter and a second splitter connected in series.

27.    A module according to claim 26 wherein said splitter components includes a third splitter connected in series with said first splitter and in parallel with said second splitter.

28. A module according to claim 22 wherein said cover and said front face include an electrically conductive, mechanically deformable seal therebetween.

29. A module according to claim 22 further comprising electrically conductive, mechanically resilient conductors extending between said front face and said layer of  
5 conductive material.

30. A module according to claim 22 wherein said front face includes a protruding ledge disposed to support a leading edge of said circuit card.

31. A module according to claim 22 wherein said circuit components include a directional coupler for diverting a portion of said main signal to a connector location  
10 connected to a monitor coax connector.

32. A module according to claim 31 wherein said monitor coax connector is exposed on said front face.

33. A module for containing a circuit for performing discrete circuit functions on a radio frequency signal, said module comprising:

15 a housing of electrically conductive material defining an enclosed interior;

said housing having a front face and an opposite rear face separated by opposite sidewalls and opposite end walls;

20 a plurality of coax connectors secured to said rear face with an outer shield of said connectors electrically coupled to said housing;

a circuit board contained within said interior and positioned generally parallel to and spaced between said sidewalls;

said circuit board having a component side opposing a first of said sidewalls and a ground side opposing a second of said sidewalls;

25 said ground side including a layer of electrically conductive material electrically connected to said housing;

a plurality of connection locations on said circuit board, each of said connection locations including a ground connection for connecting to said layer of electrically conductive material;

30 said component side of said circuit board including a plurality of circuit components interconnected with one another and with said connection locations through a plurality of circuit paths;

said coax connectors connected to said connection locations, each of said outer shields of said coax connectors connected to said ground connections of said connection locations;

5           said plurality of components including a directional coupler;  
          an equalizer for equalizing a radio frequency signal along a frequency range;

          said equalizer including a first equalizer component mounted on said component side of said circuit board and a variable equalizer component removably secured to said first component with said variable equalizer component selected for a  
10   fixed desired radio frequency equalization;

          said equalizer positioned adjacent said front face;

          said front face having an opening sized to pass said second variable equalizer component through said front face; and

          an electrically conductive cover releasably secured to said front face  
15   and sized to cover said opening.

34.    A module according to claim 33, including a plurality of coax cables disposed within said interior and connecting said coax connectors to said connection locations, each of said coax cables having ground shields connected to said outer  
20   shields of said coax connectors and to said ground connections of said connection locations, said plurality of cables routed for said cables to be disposed between said ground side of said circuit board and said second of said sidewalls.

35.    A module according to claim 33 wherein said circuit paths are sized to have an impedance selected to balance a parasitic reactance between said circuit board  
25   and said housing.

36.    A module according to claim 33 wherein said circuit components include a directional coupler.

37.    A module according to claim 36 wherein said components include an equalizer for equalizing a radio frequency signal along a frequency range.

30   38.    A module according to claim 37 wherein:  
          said equalizer is positioned adjacent said front face;  
          said front face having an opening sized to pass said second variable equalizer component through said front face;

an electrically conductive cover releasably secured to said front face and sized to cover said opening.

39. A module for containing a circuit for performing discrete circuit functions on a radio frequency signal, said module comprising:

5 a housing of electrically conductive material defining an enclosed interior;

said housing having a front face and an opposite rear face separated by opposite sidewalls and opposite end walls;

10 a plurality of coax connectors secured to said rear face with an outer shield of said connectors electrically coupled to said housing;

a circuit board contained within said interior and positioned generally parallel to and spaced between said sidewalls;

said circuit board having a component side opposing a first of said sidewalls and a ground side opposing a second of said sidewalls;

15 said ground side including a layer of electrically conductive material electrically connected to said housing;

a plurality of connection locations on said circuit board, each of said connection locations including a ground connection for connecting said layer of electrically conductive material;

20 said component side of said circuit board including a plurality of circuit components interconnected with one another and with said connection locations through a plurality of circuit paths;

25 said coax connectors connected to said connection locations, each of said outer shields of said coax connectors connected to said ground connections of said connection locations;

said plurality of components including a plurality of directional couplers for receiving a plurality of branch signals delivered along said circuit paths and combining said branch circuits into a main signal at one of said connection locations;

30 said circuit components include a plurality of attenuators associated with individual ones of said branch circuits;

35 said attenuators including a first attenuator component mounted on said component side of said circuit board and a variable attenuator component removably secured to said first component with said variable attenuator component selected for a fixed desired attenuation;

said attenuators positioned adjacent said front face;



said front face having an opening sized to pass said second variable attenuator component through said front face; and

an electrically conductive cover releasably secured to said front face and sized to cover said opening.

5

40. A module according to claim 39, including a plurality of coax cables disposed within said interior and connecting said coax connectors to said connection locations, each of said coax cables having ground shields connected to said outer shields of said coax connectors and to said ground connections of said connection  
10 locations, said plurality of cables routed for said cables to be disposed between said ground side of said circuit board and said second of said sidewalls.

41. A module according to claim 39 wherein said circuit paths are sized to have an impedance selected to balance a parasitic reactance between said circuit board and said housing.

15 42. A module according to claim 39 wherein said cover and said front face include an electrically conductive, mechanically deformable seal disposed within said recess.

43. A module according to claim 39 wherein said front face includes electrically  
20 conductive, mechanically resilient conductors extending between said front face and said layer of conductive material.

44. A module according to claim 43 wherein said front face includes a protruding ledge disposed to support a leading edge of said circuit card.

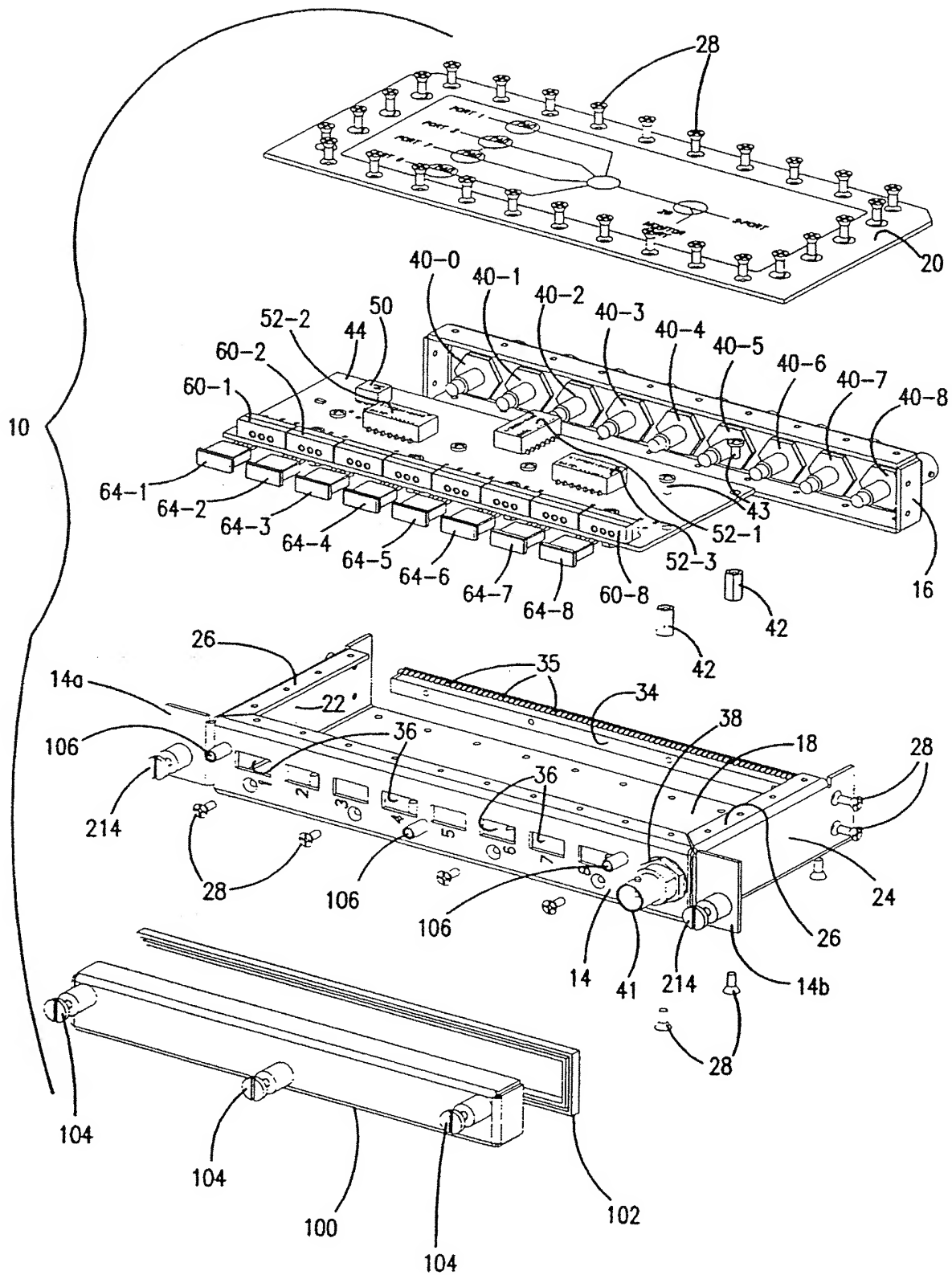
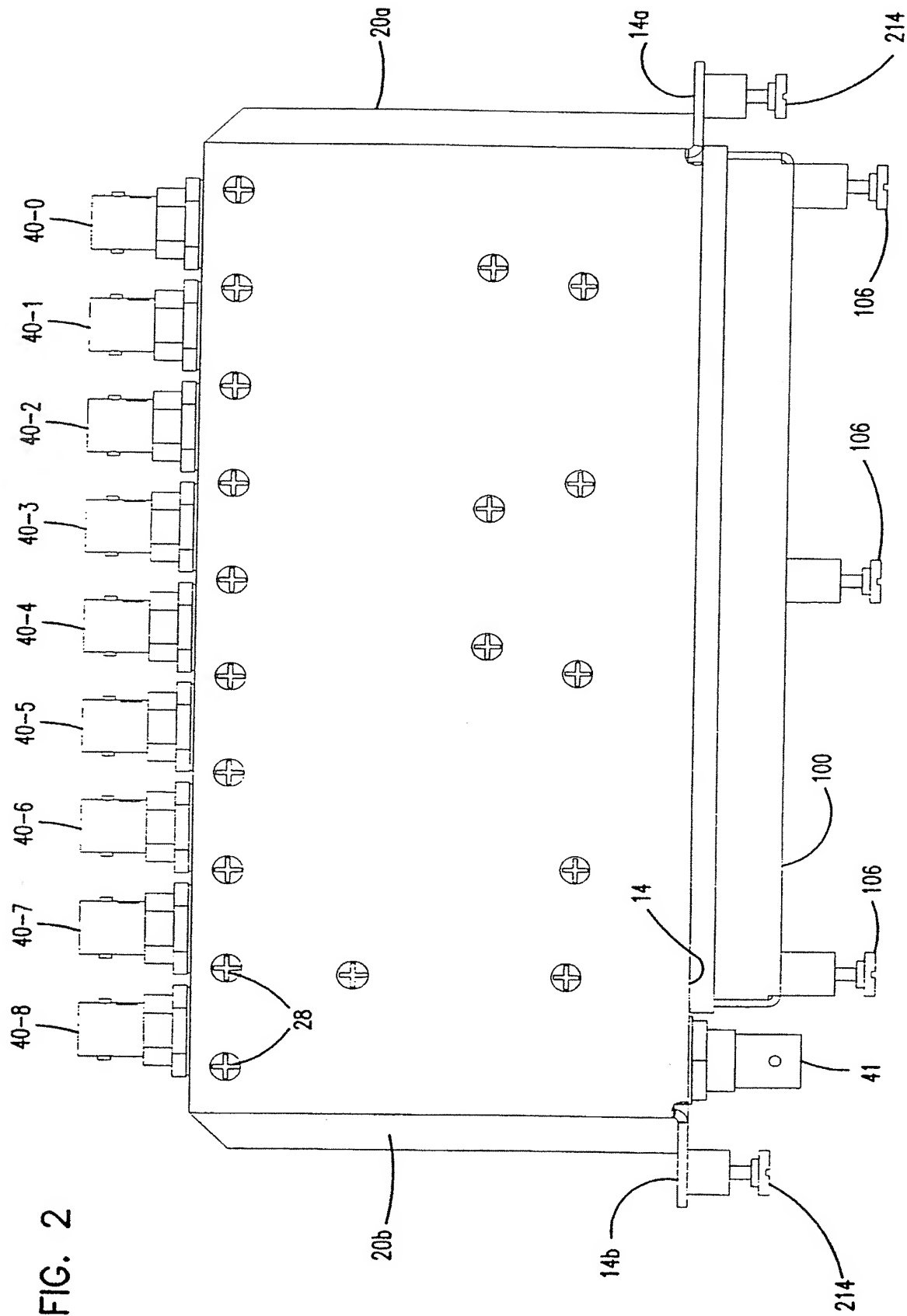


FIG. 1



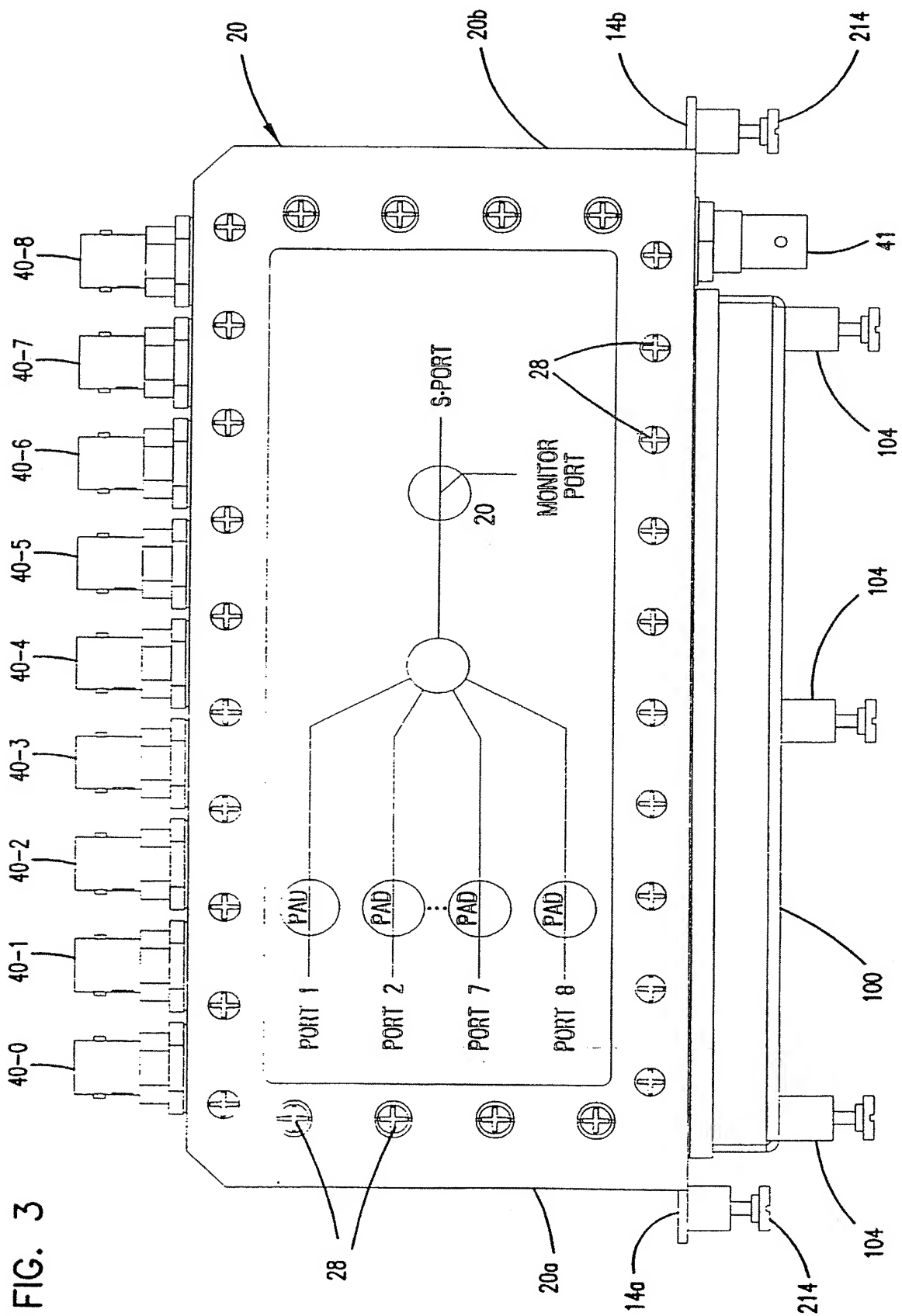


FIG. 4

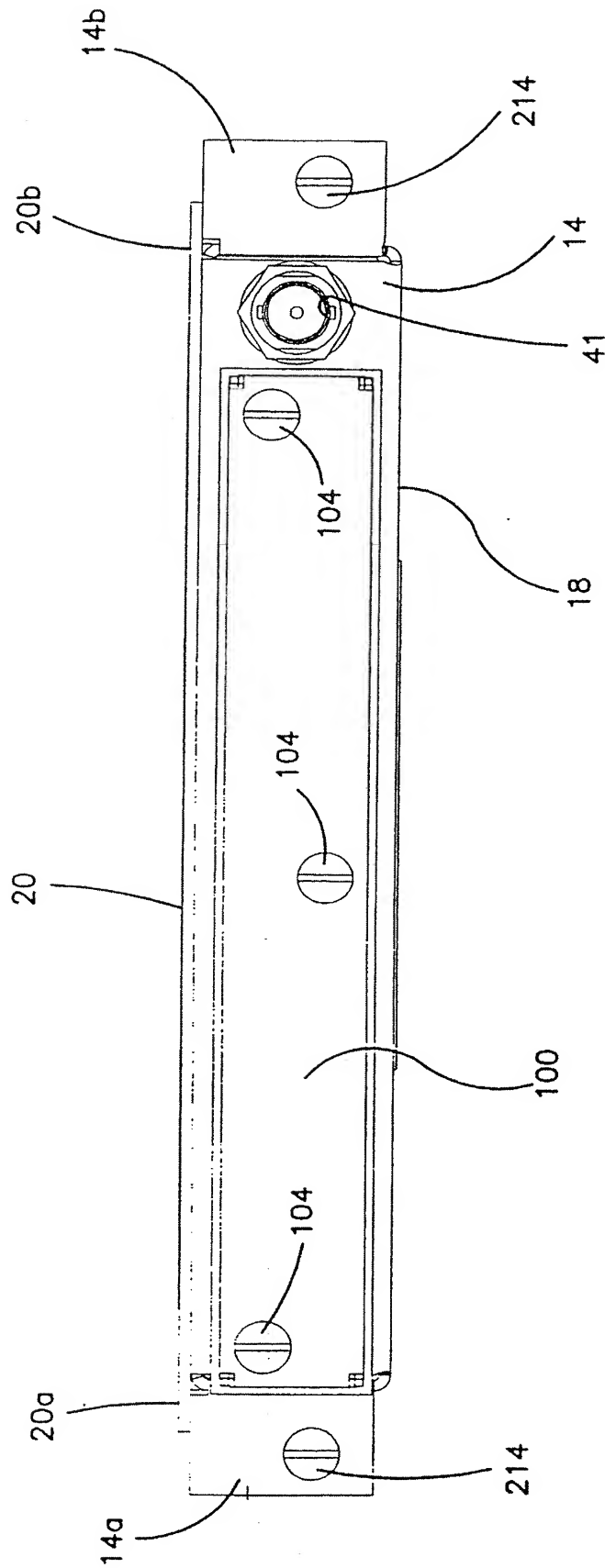


FIG. 5

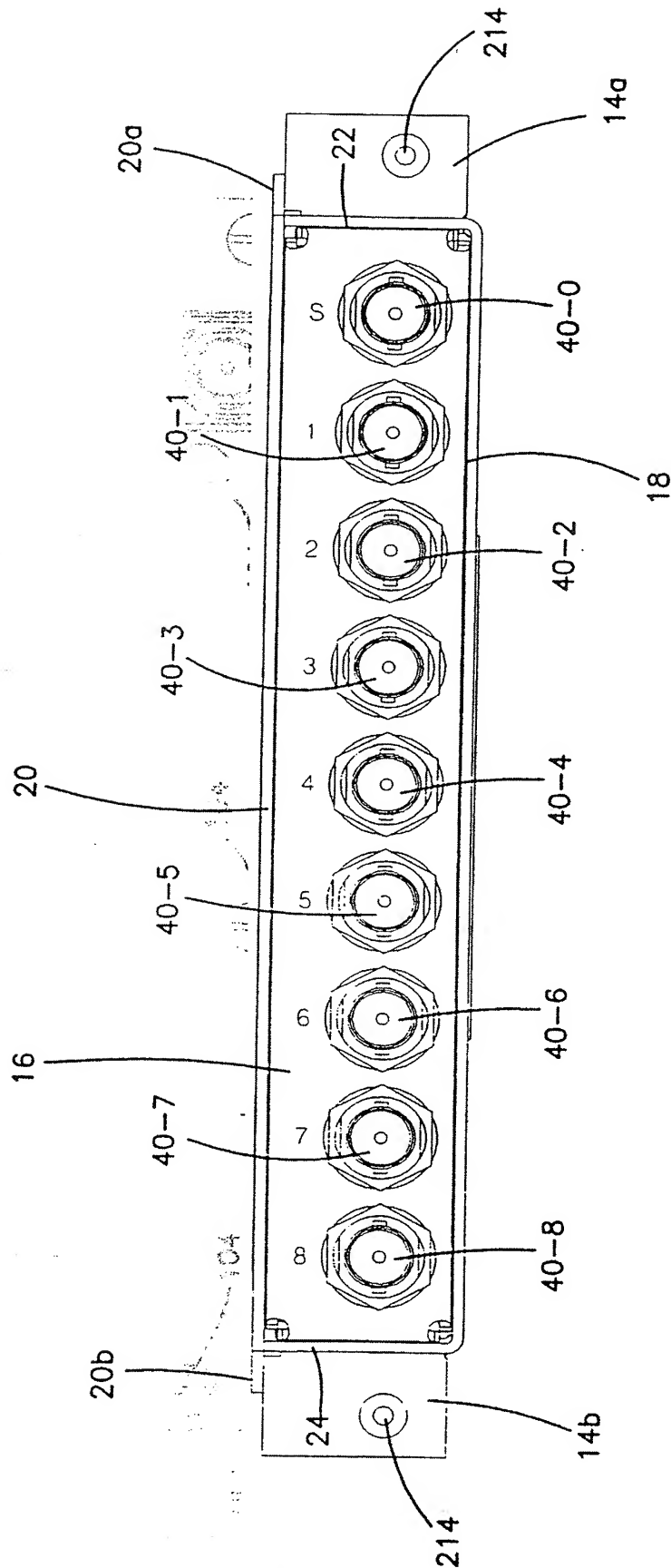


FIG. 6

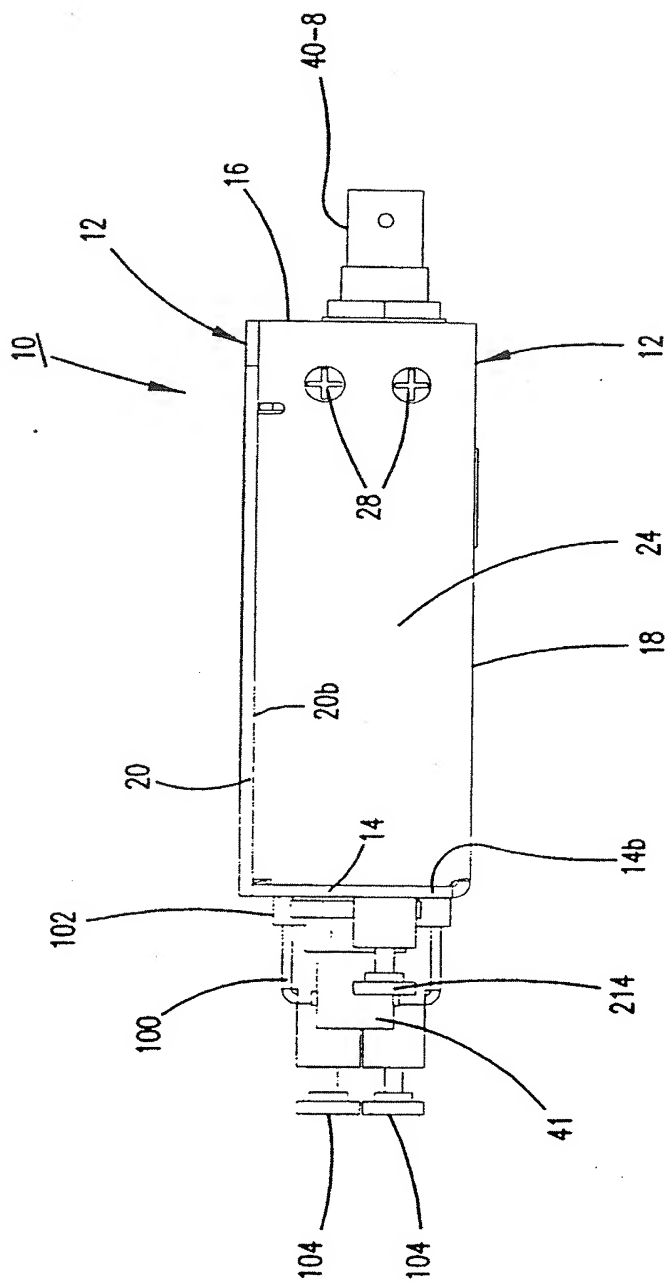


FIG. 7

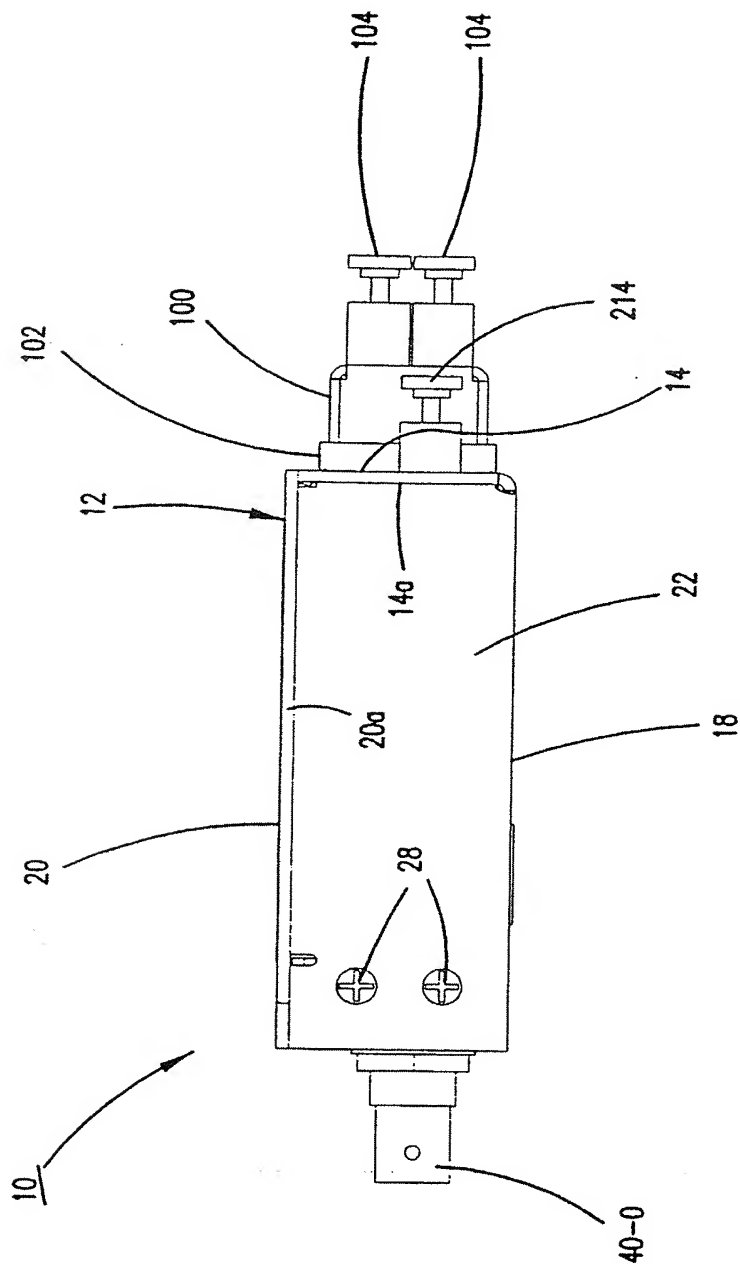




FIG. 8

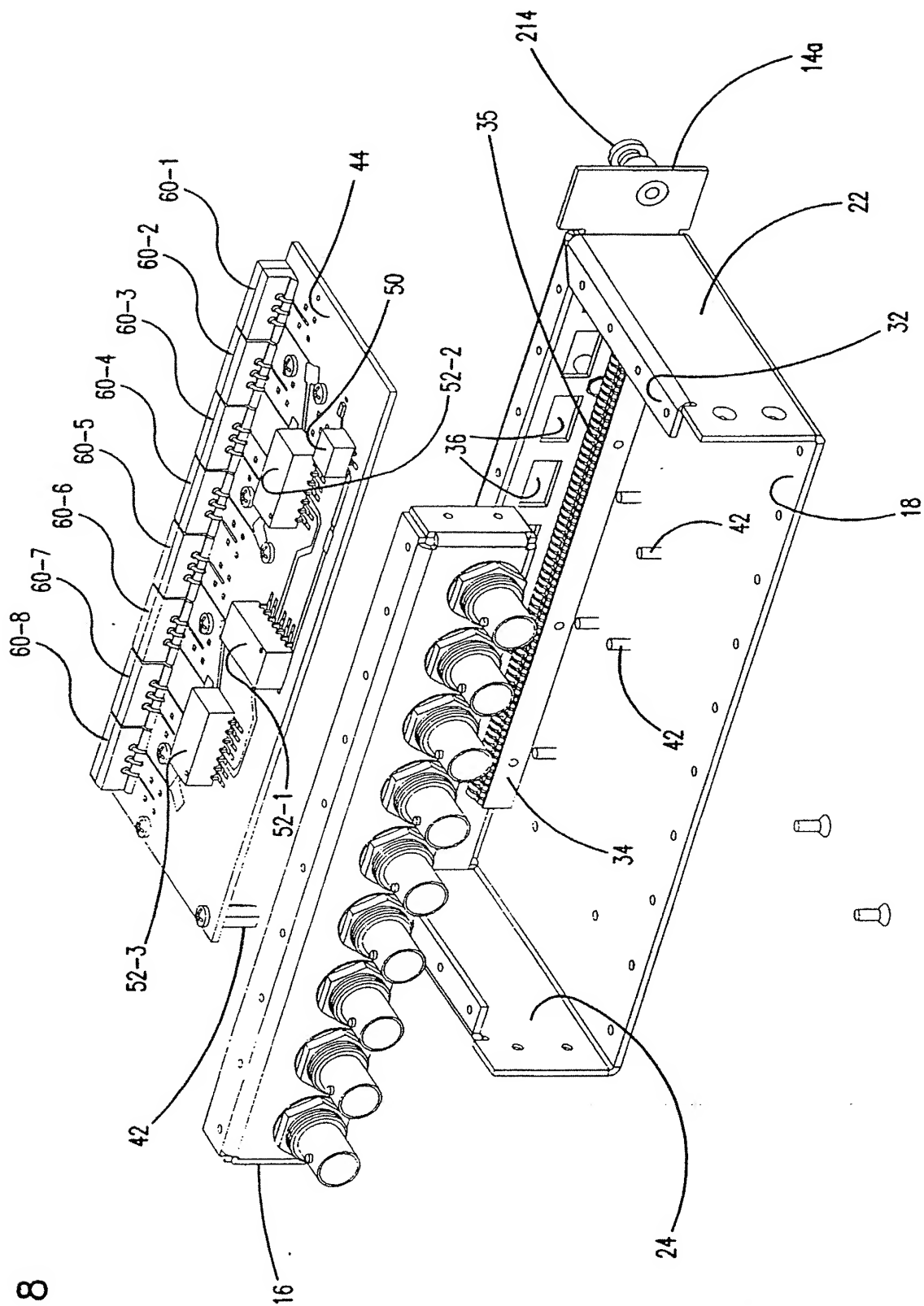


FIG. 9

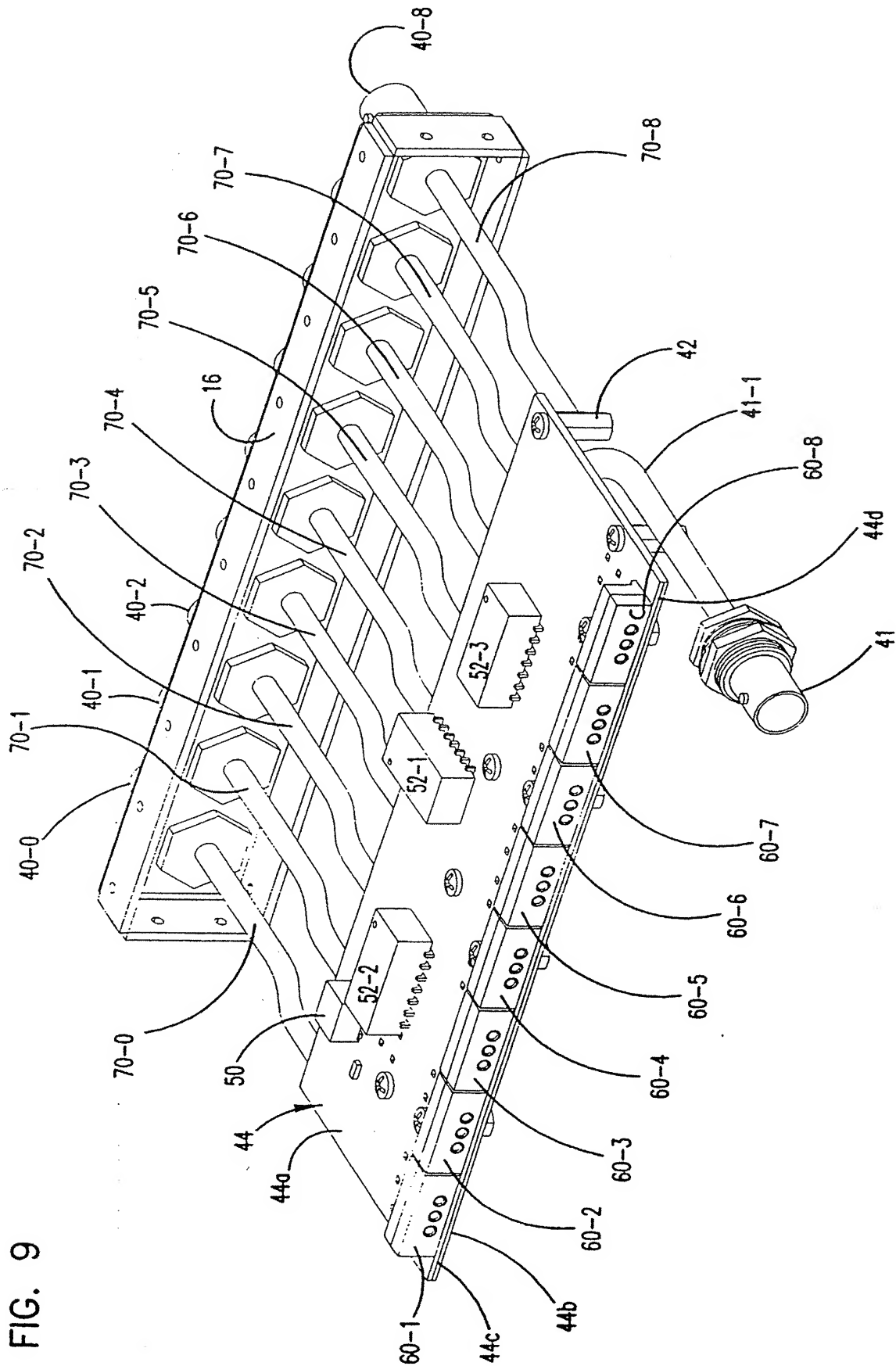


FIG. 9A

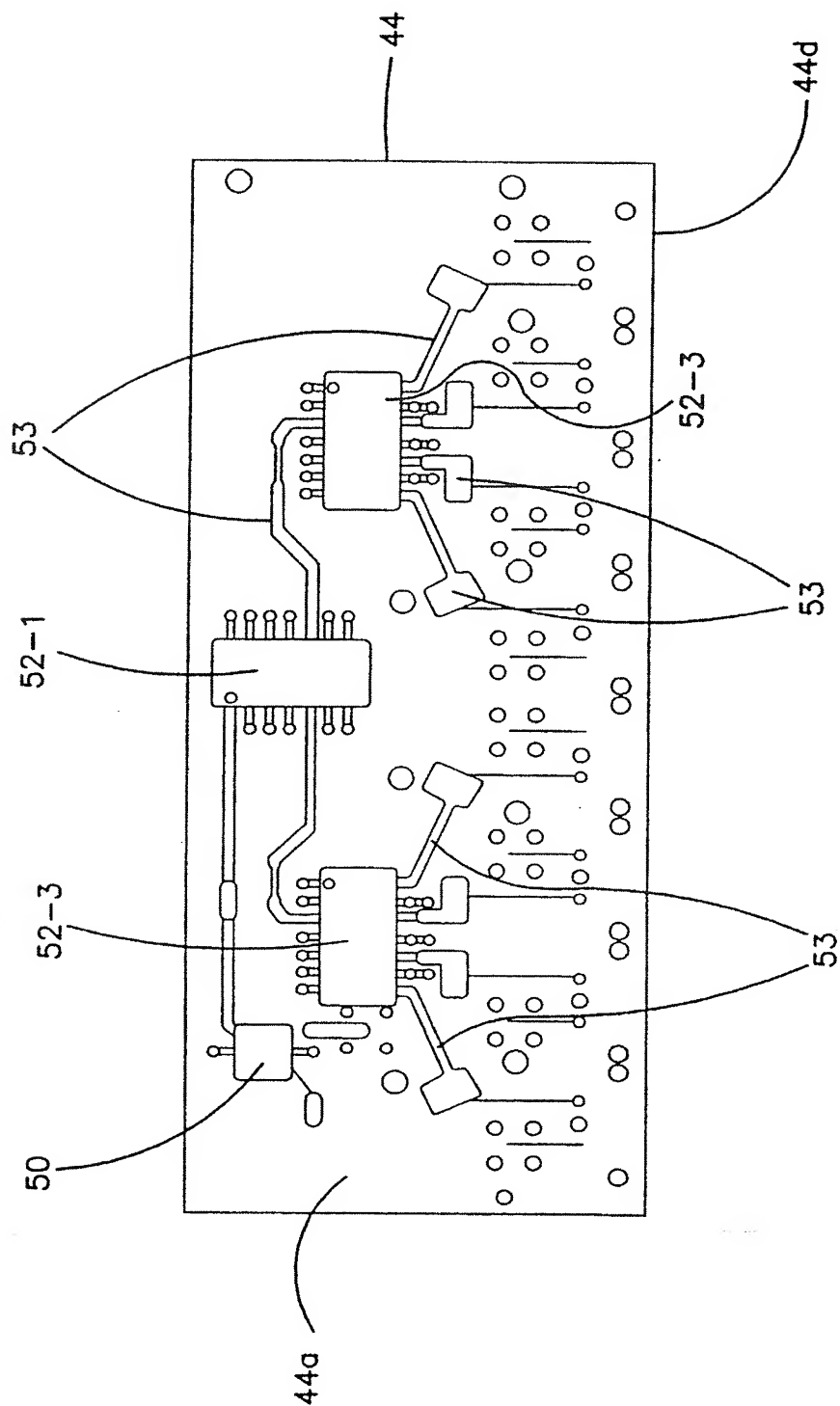


FIG. 10

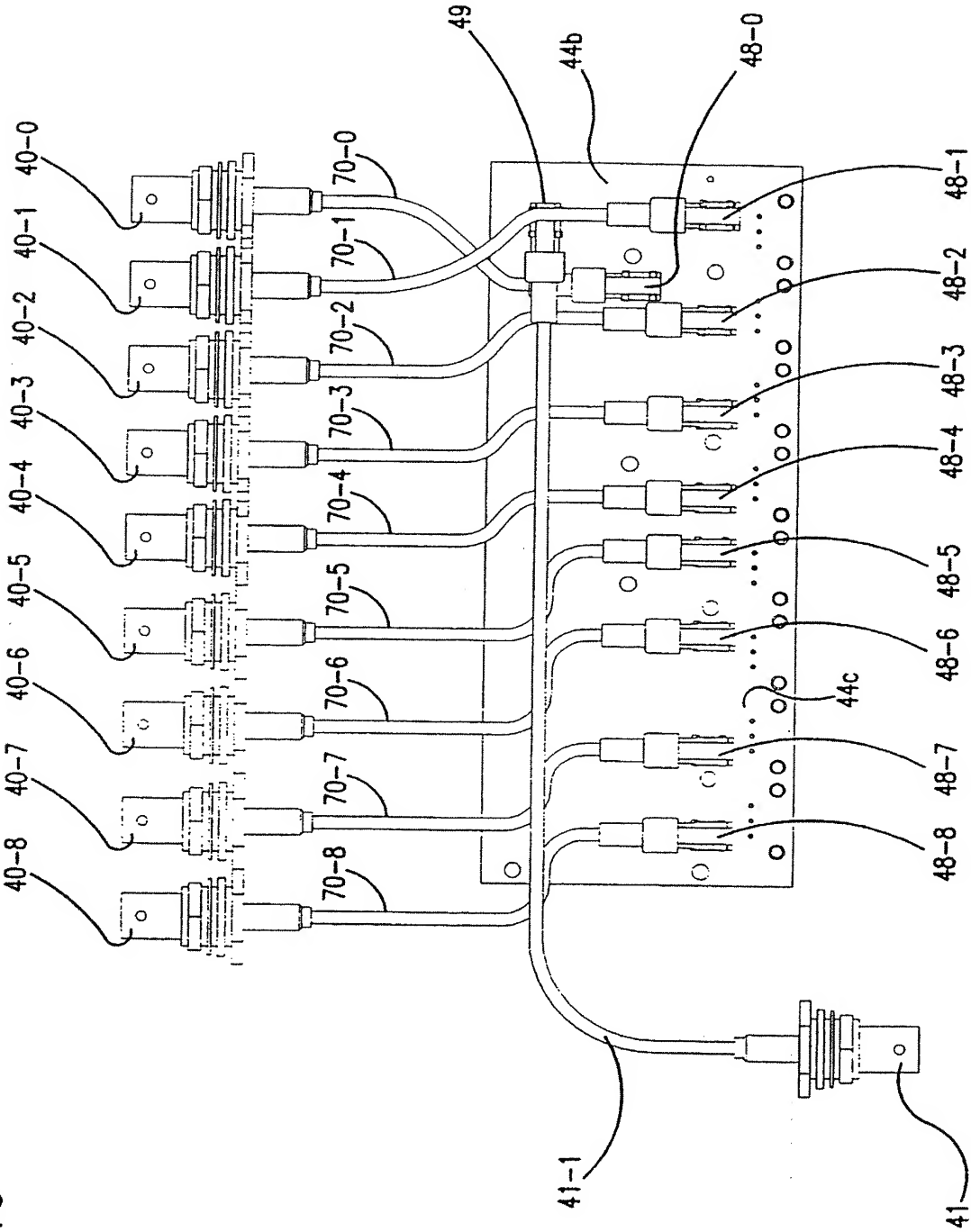
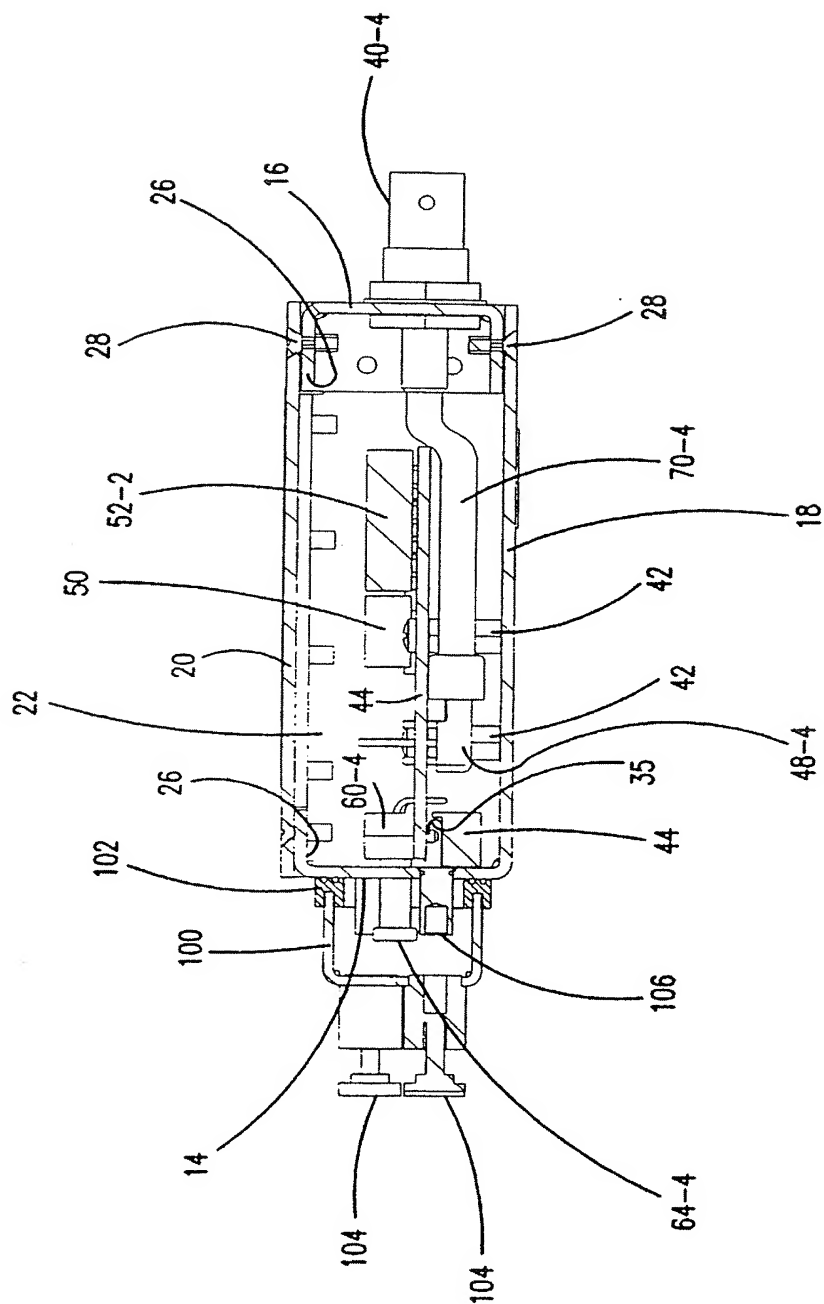


FIG. 11



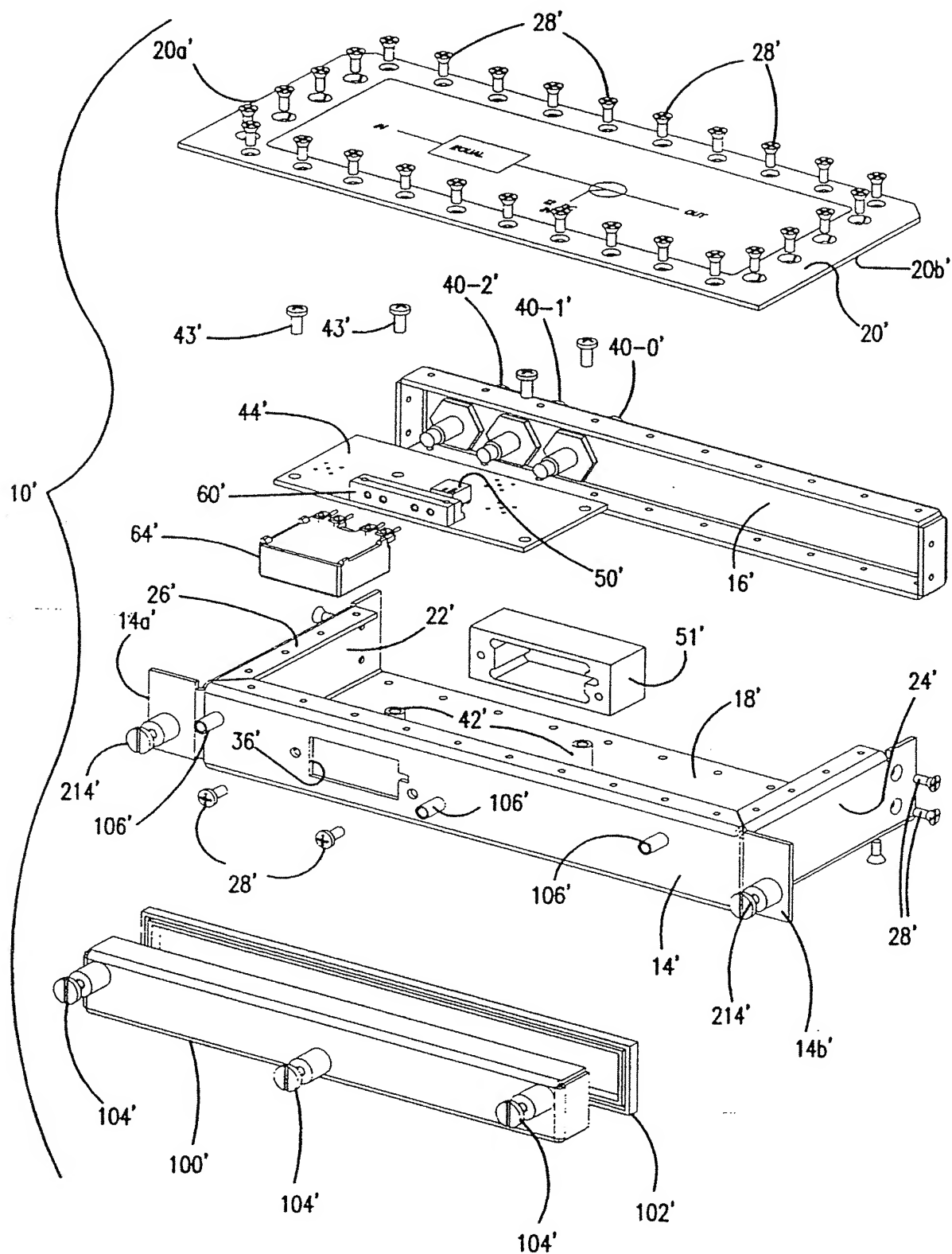
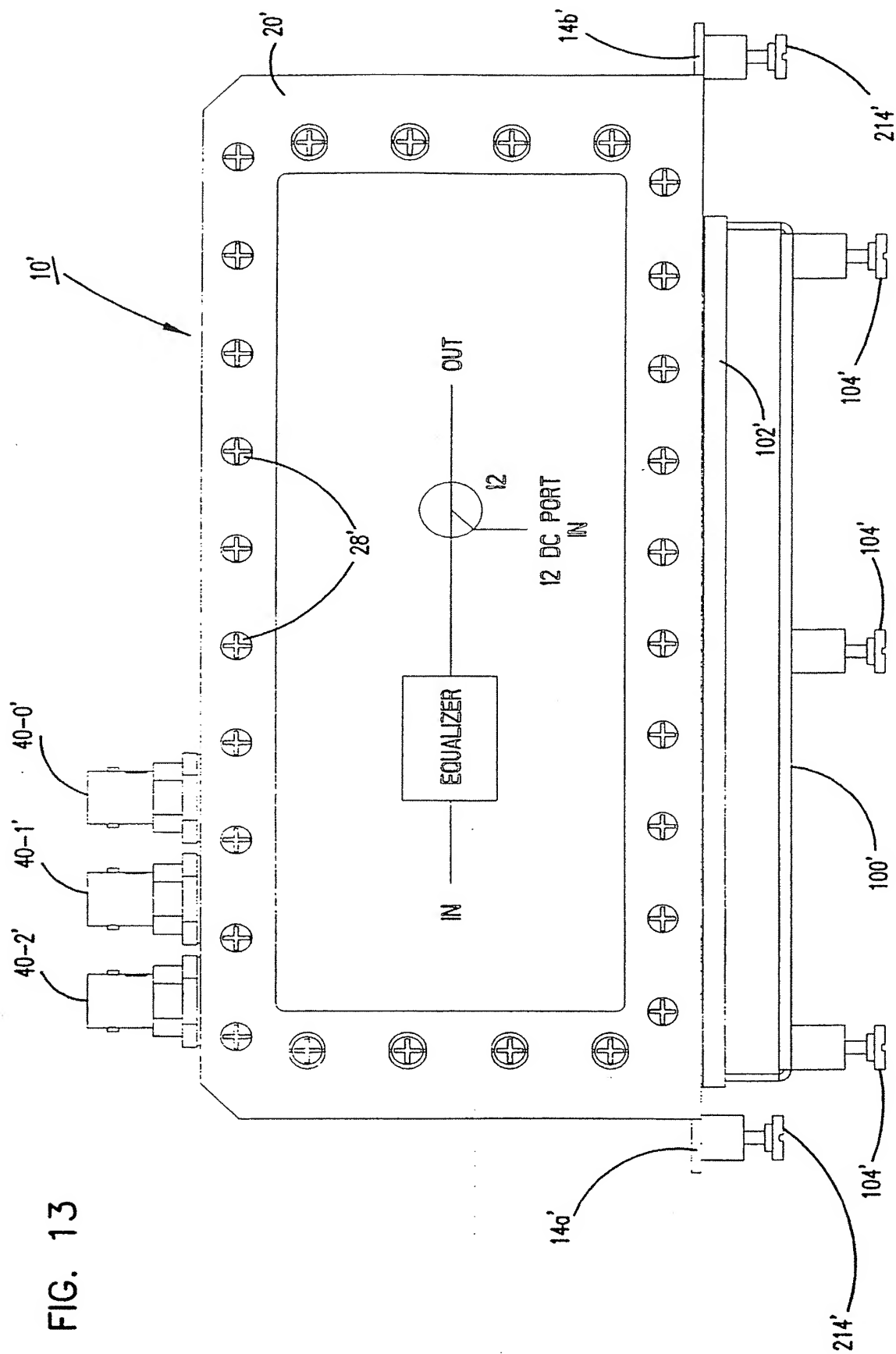


FIG. 12



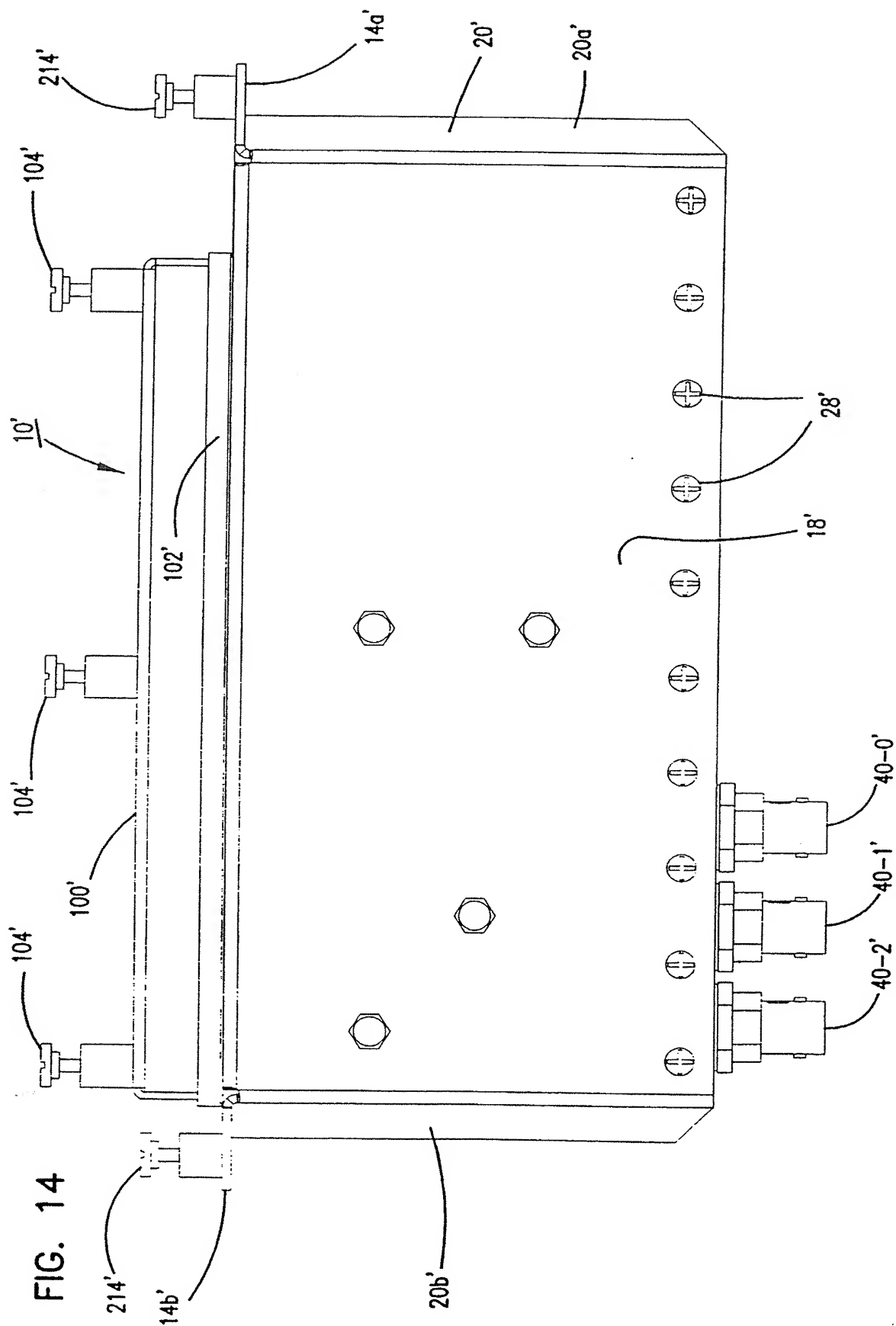




FIG. 15

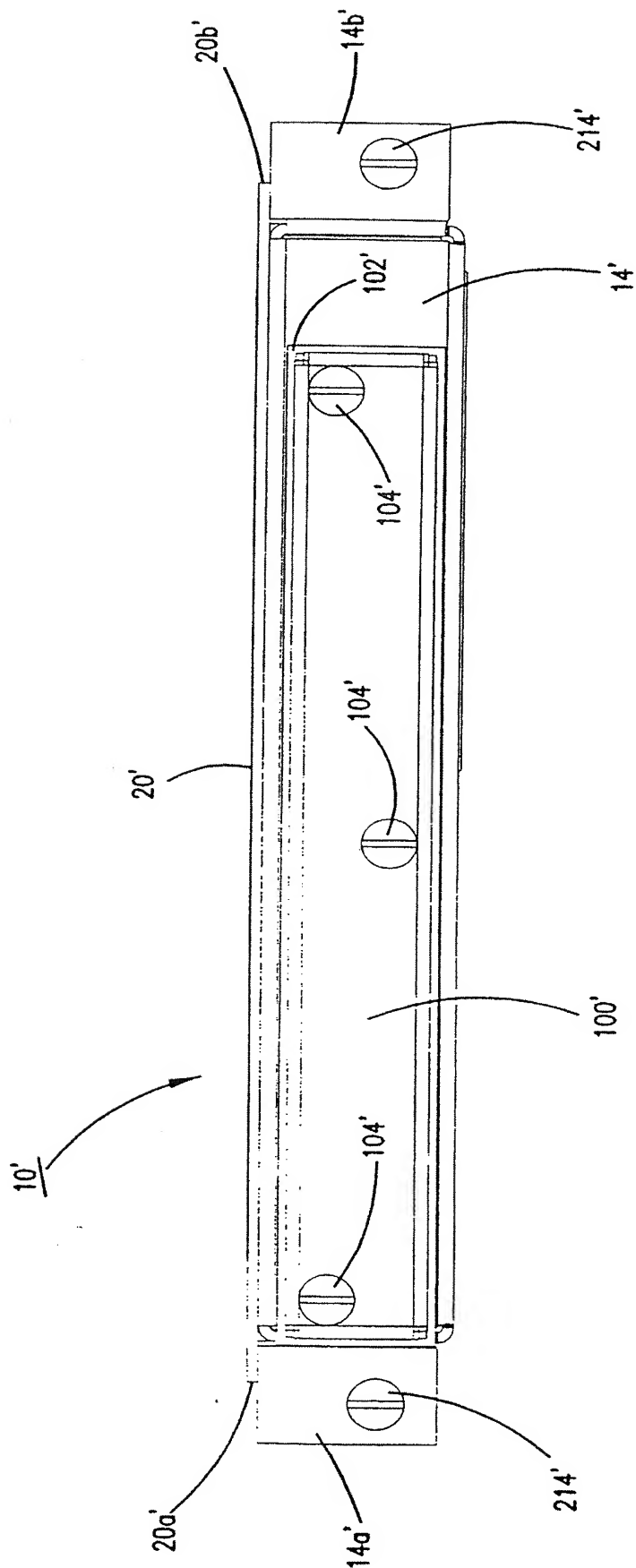


FIG. 16

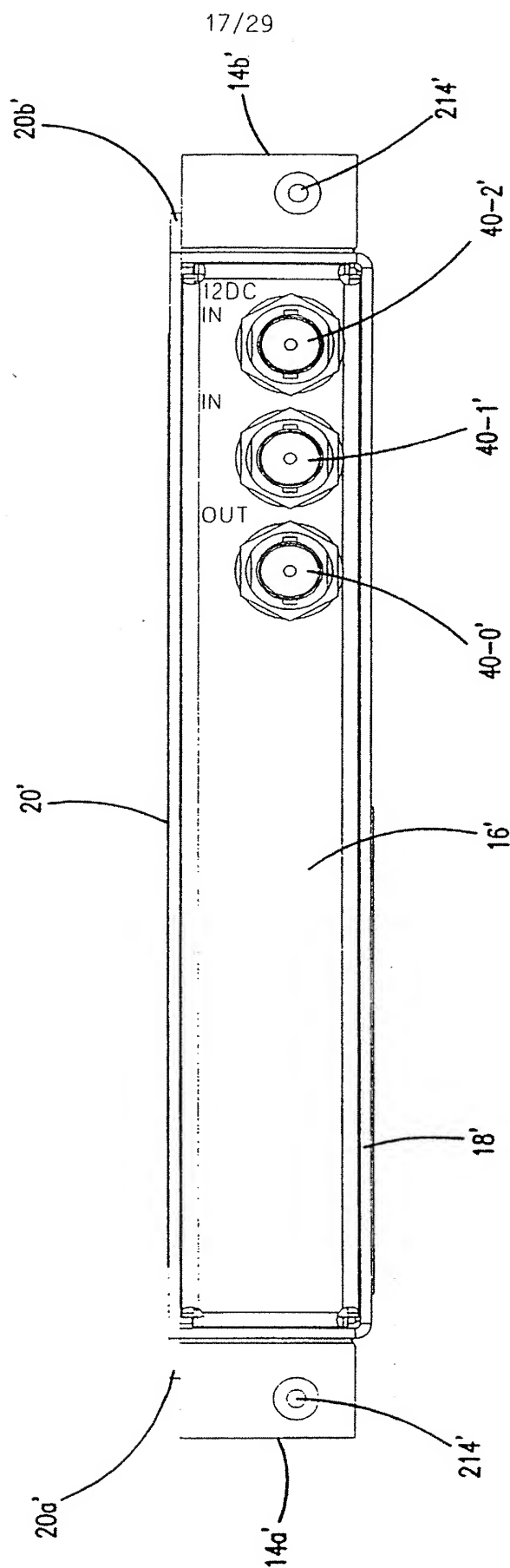


FIG. 17

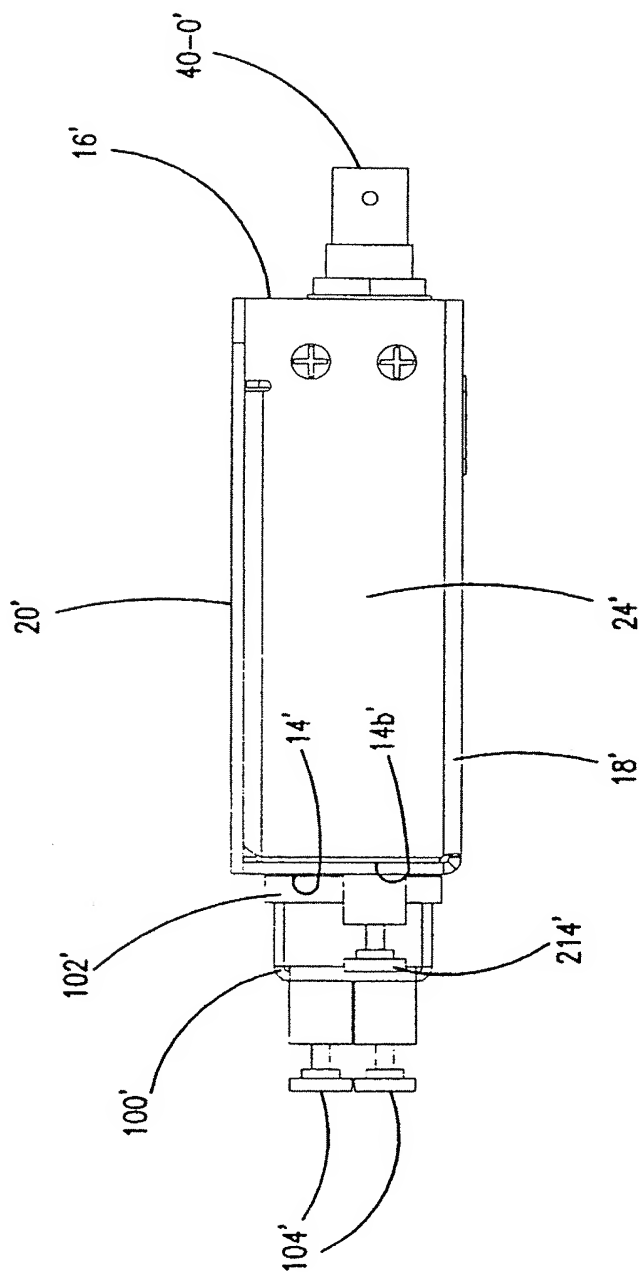
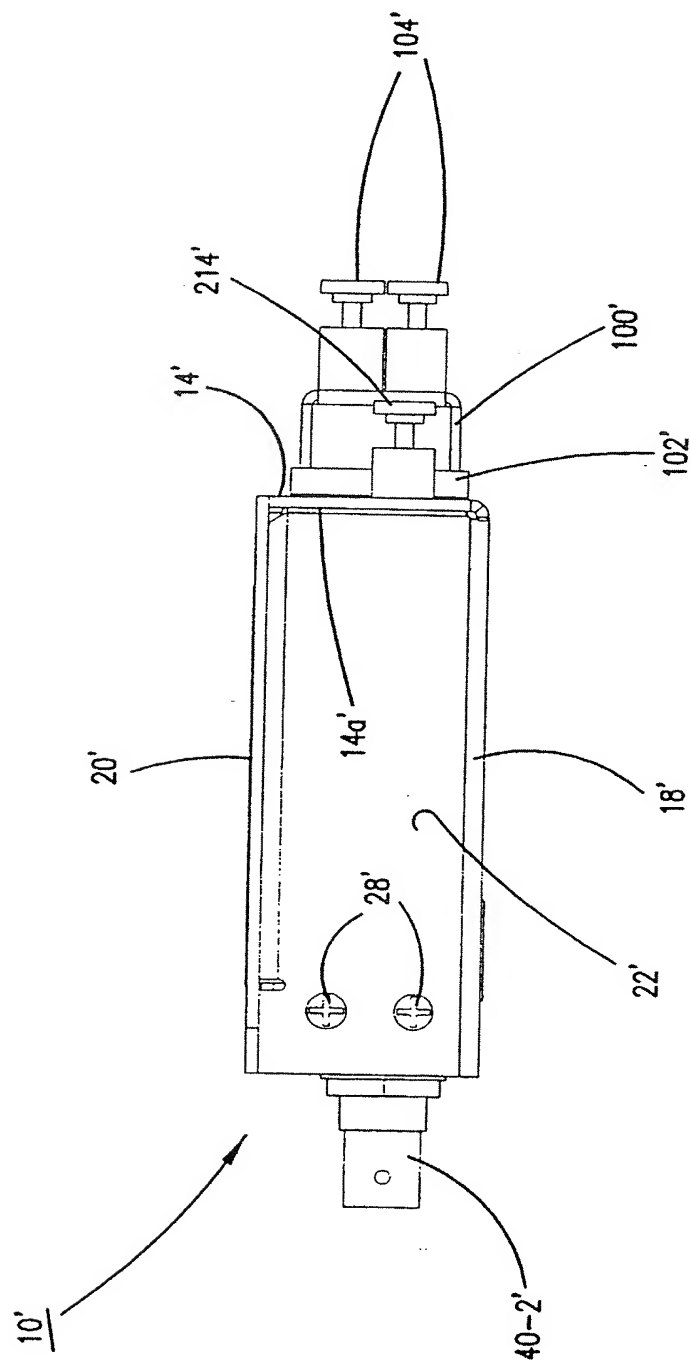


FIG. 18



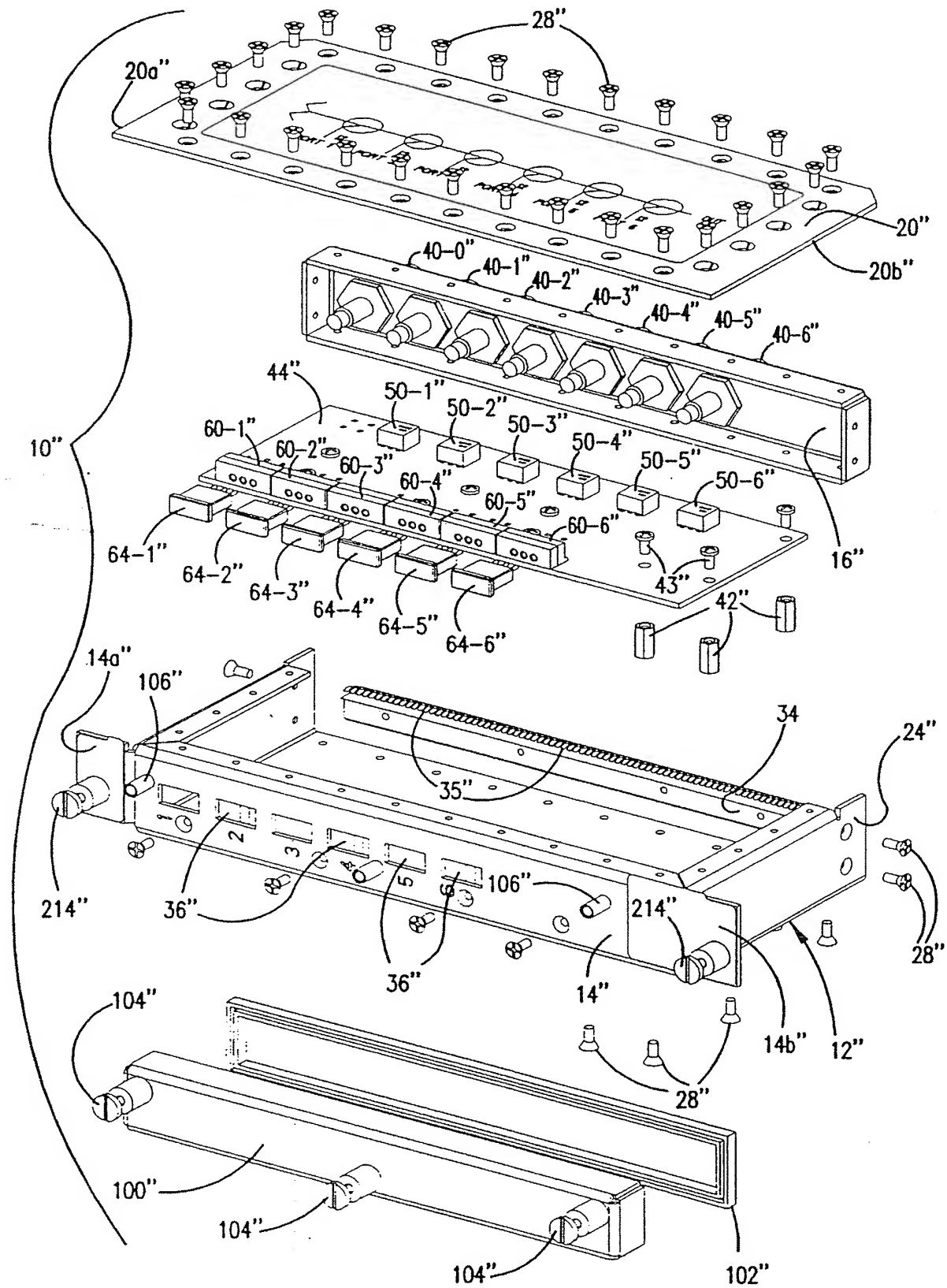
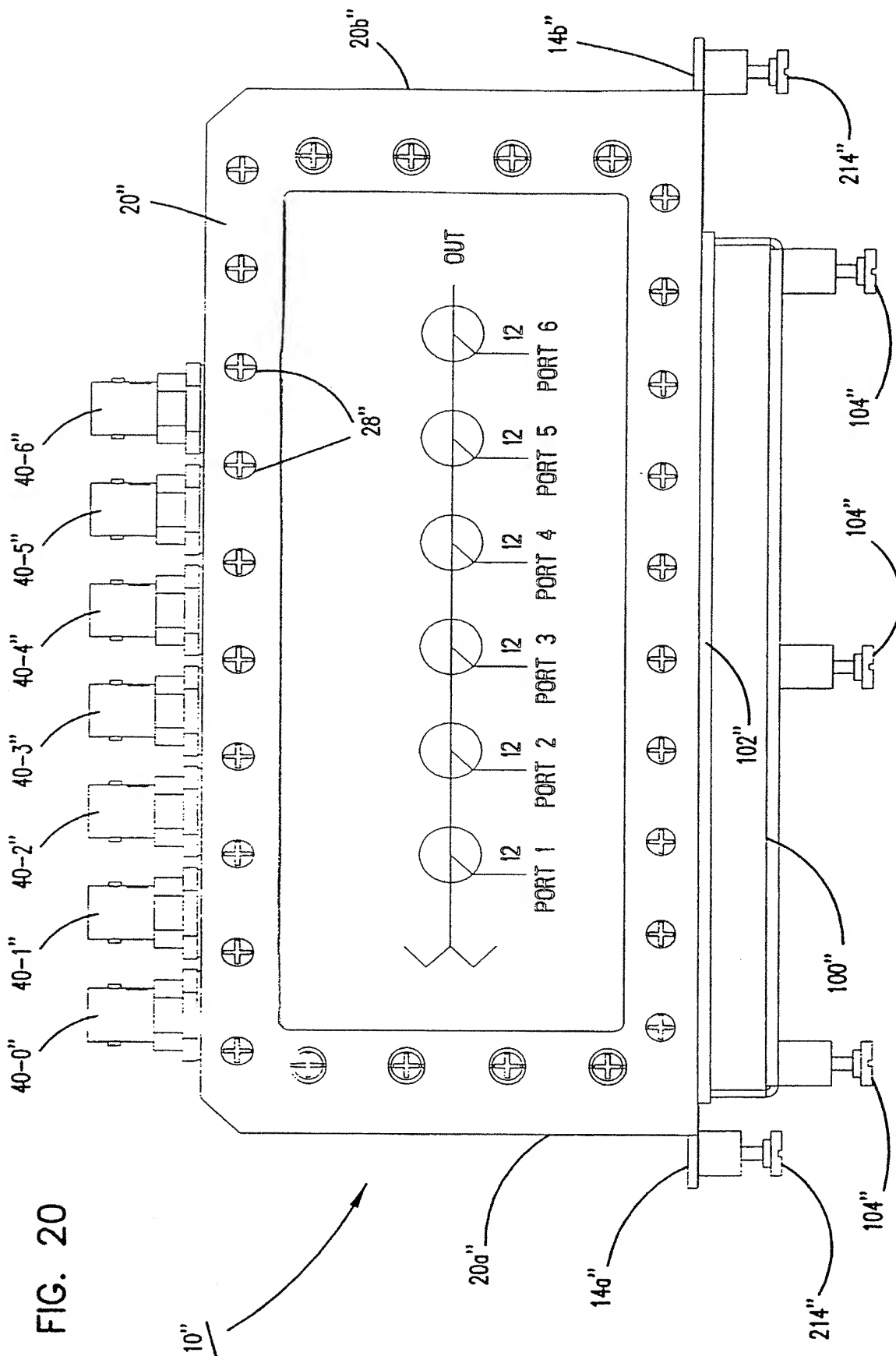


FIG. 19



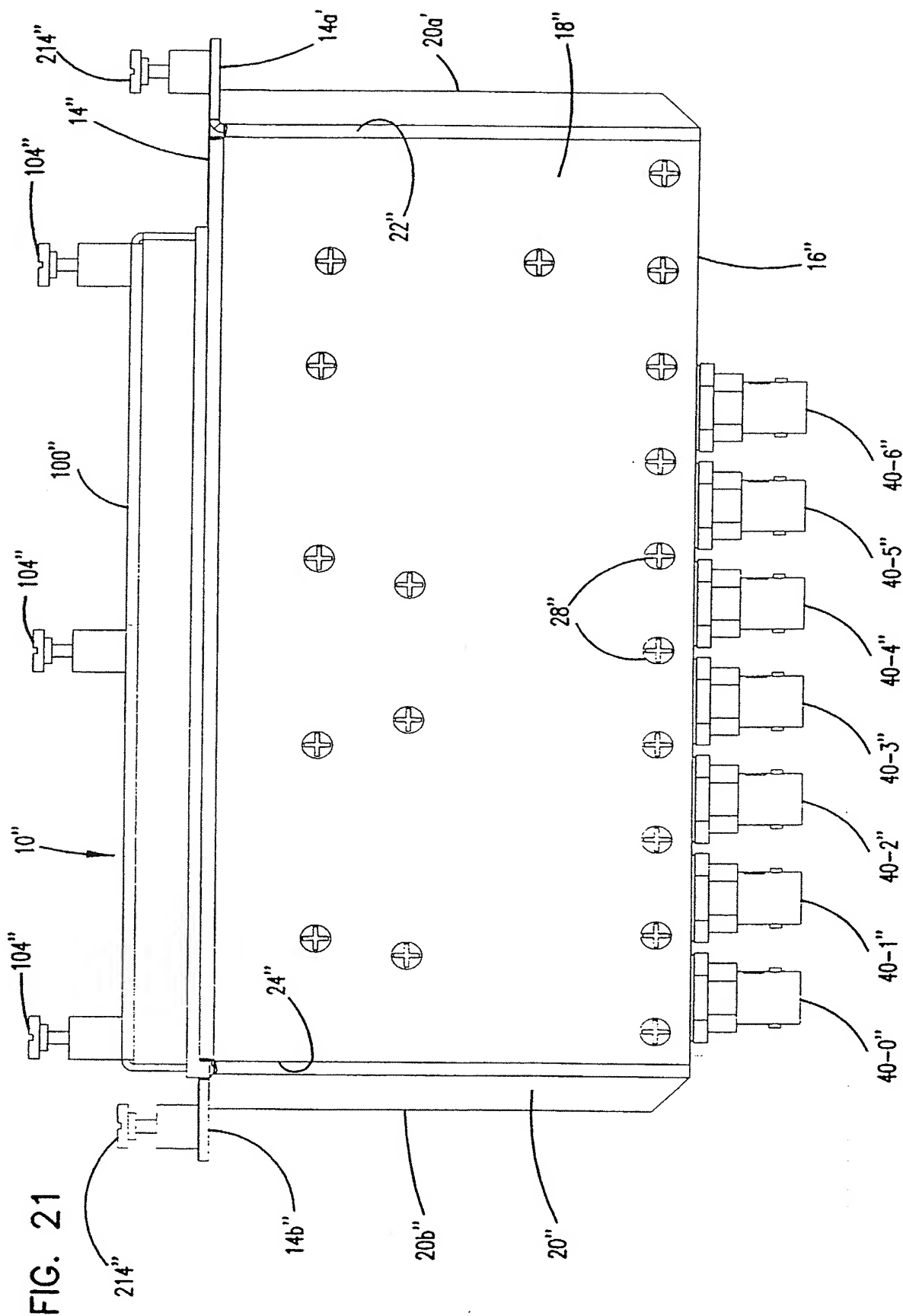


FIG. 22

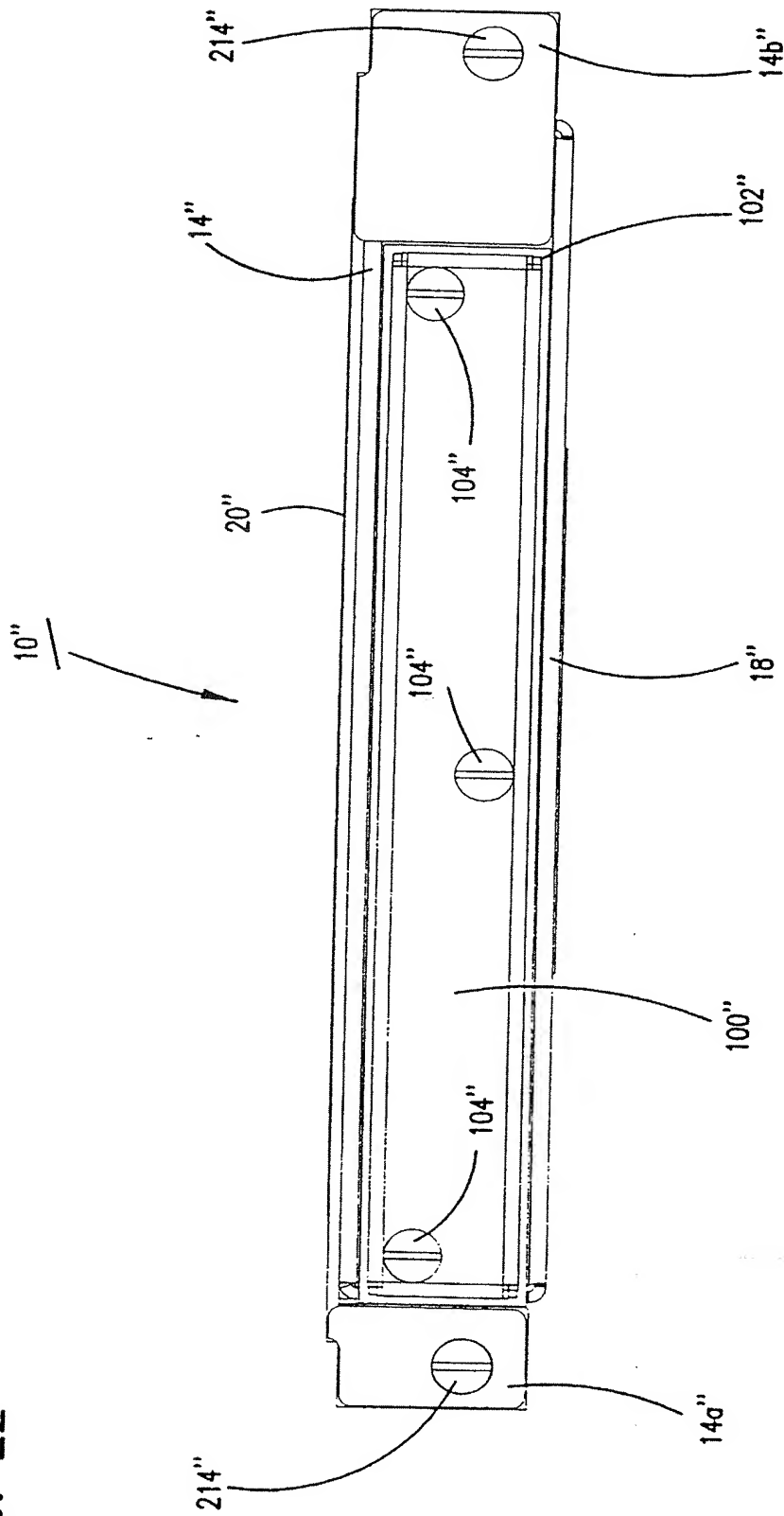




FIG. 23

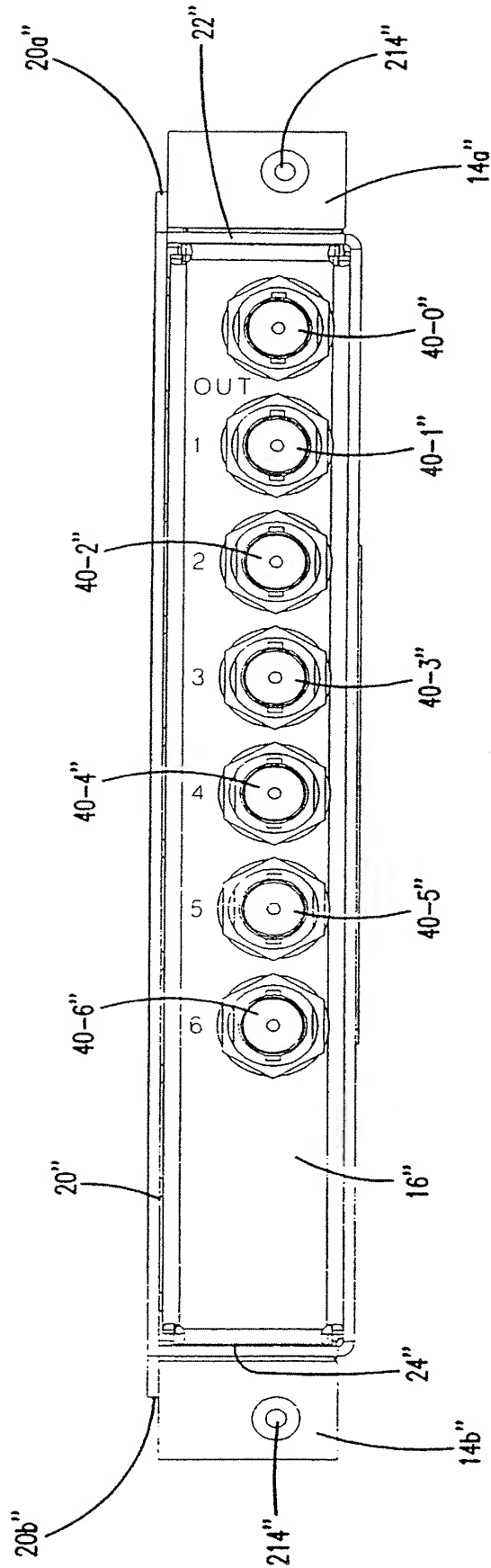


FIG. 24

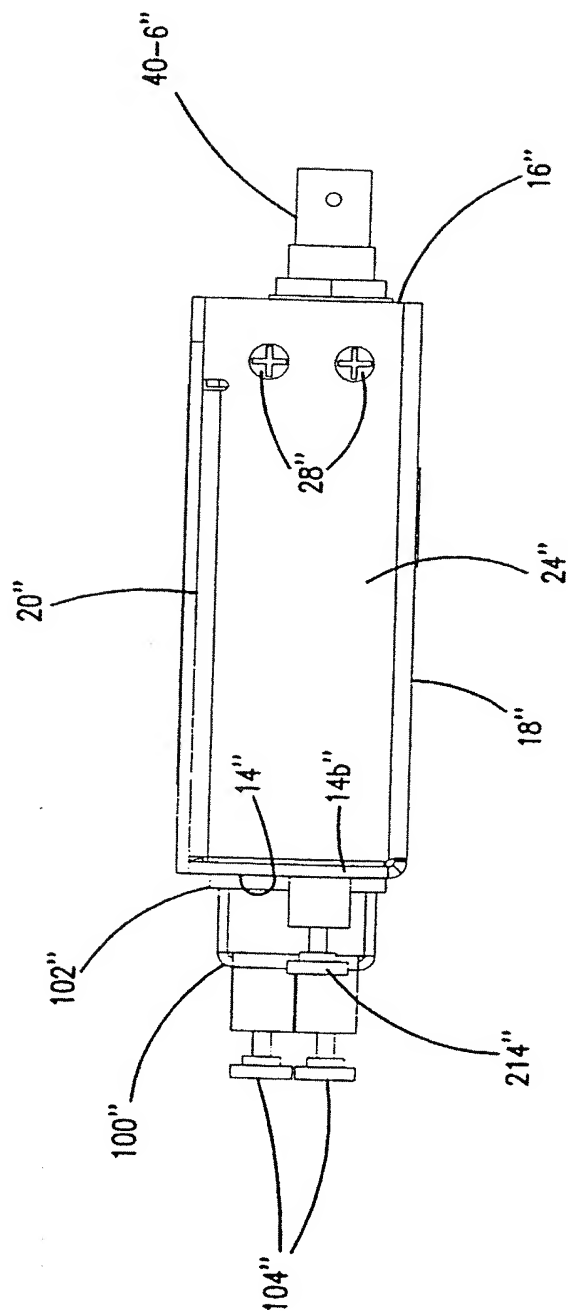
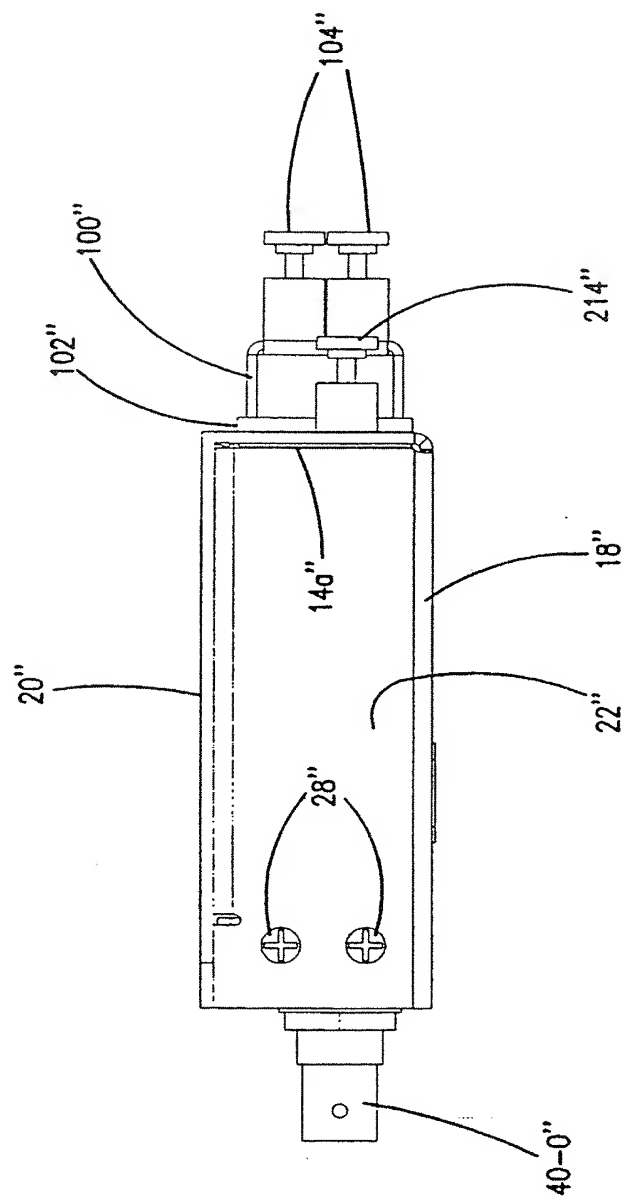


FIG. 25



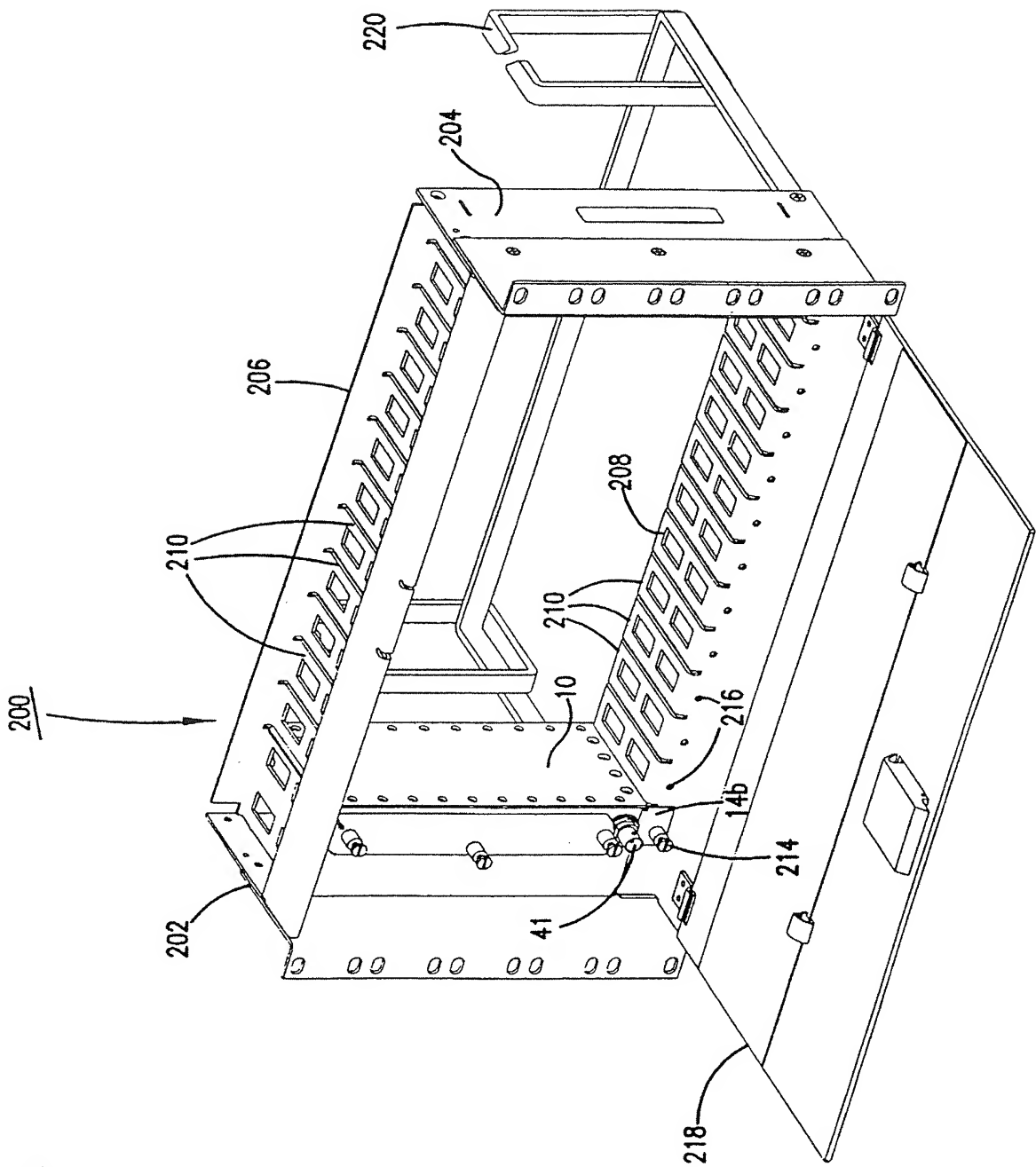


FIG. 26

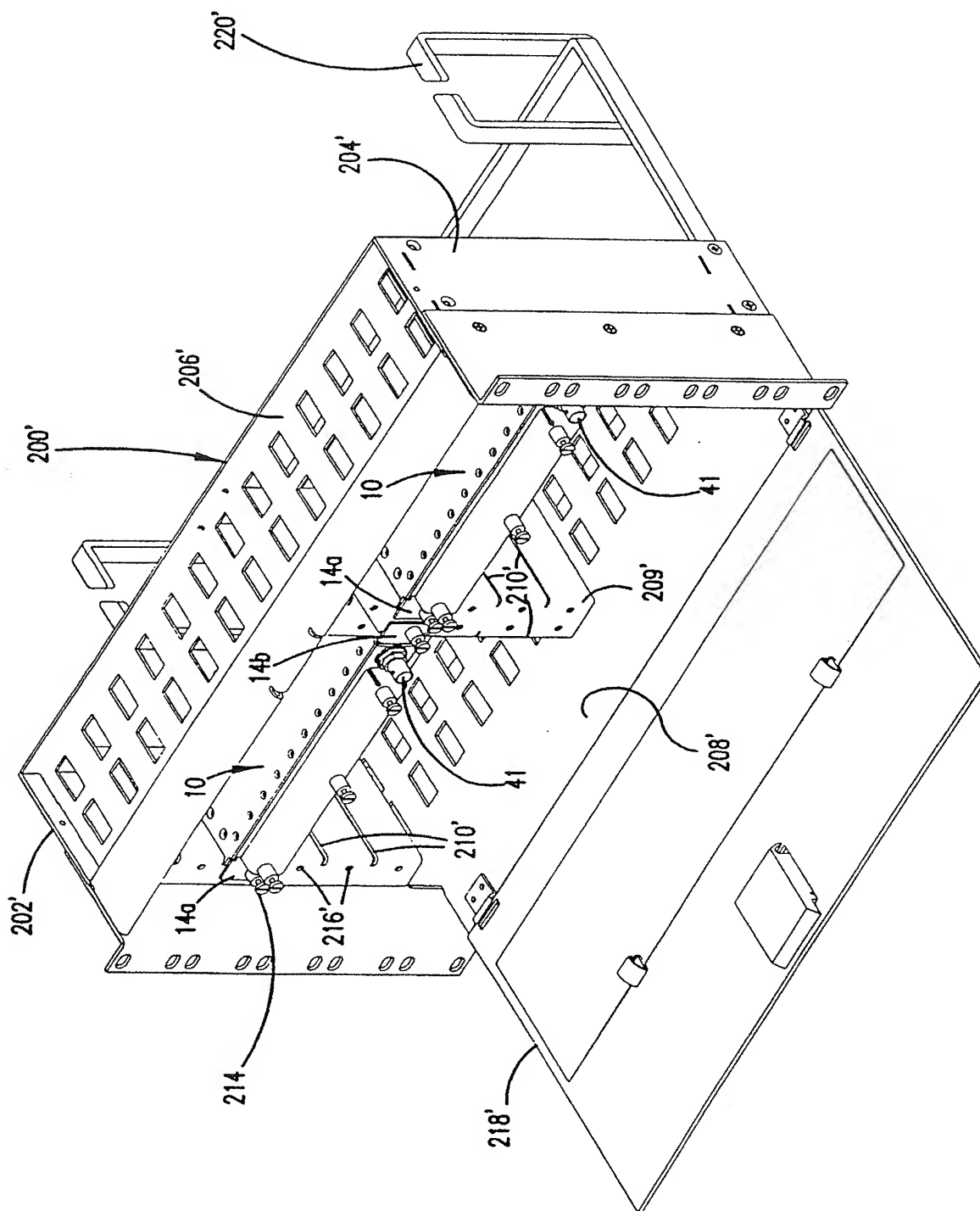
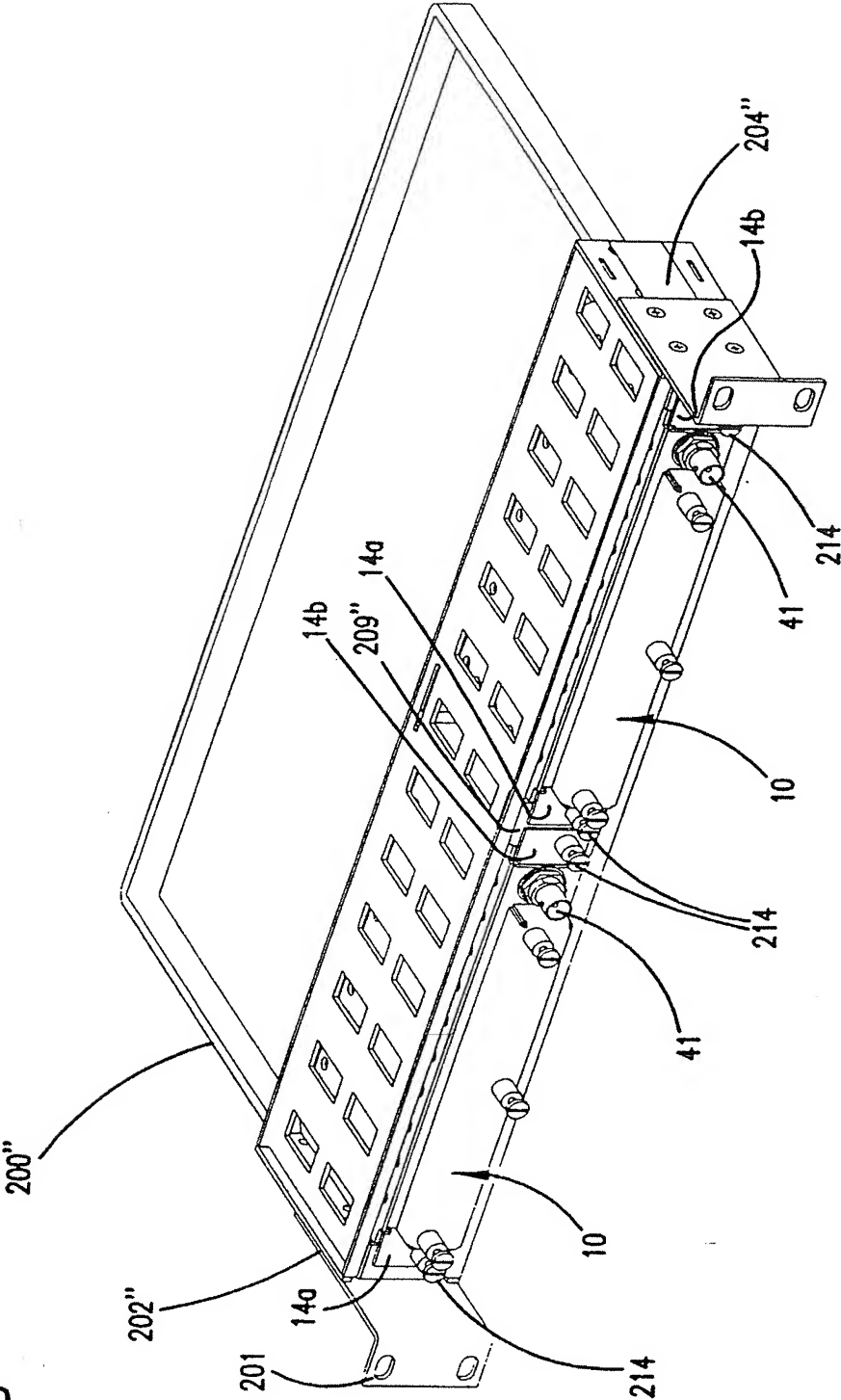


FIG. 27

FIG. 28



## INTERNATIONAL SEARCH REPORT

Inte:      onal Application No  
PCT/US 97/22556

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6    H0401/14    H01R17/12    H04N7/10

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6    H04Q    H01R    H04N    H05K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 546 282 A (HILL TIMOTHY L ET AL) 13 August 1996 see the whole document ---	1, 21, 22, 33, 39
A	US 4 813 886 A (ROOS MARK D ET AL) 21 March 1989 see the whole document ---	1, 21, 22, 33, 39
A	DE 16 90 798 B (AMP) 31 May 1972  see the whole document -----	1, 21, 22, 33, 39



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents:

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search

25 March 1998

Date of mailing of the international search report

01/04/1998

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Authorized officer

Toussaint, F

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 97/22556

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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